The Researches of Low Carbon Enterprises' Eco-Efficiency Evaluation in Shandong Province

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Abstract: At present, sustainable and environmental issue has become constraining bottleneck for China's rapid development. Efficiency improving, energy saving, emission reduction and low-carbon development will be inevitable choices for our country's future development. However, in many provinces, low-carbon development are wasteful and inefficient. How can evaluate eco-efficiency of low carbon enterprises, make the acquintance of regional actual conditions, and working out a development with characteristics, low-carbon economy path, are before us major issues. In the paper, an empirical analysis of low carbon enterprises' eco-efficiency evaluation in Shanddong Province is furnished. Firstly, on the basis of calculating the weight of each index by AHP, the paper calculates the eco-efficiency evaluation comprehensive index of low carbon enterprises to provide the samples for Artificial Neural Network learning. Then, it trains and tests the sample data with Neural Network technology in order to assess comprehensive eco-efficiency evaluation of enterprises in Shanddong Province. And the analysis is recommendable to other provinces.
Keywords: Low Carbon Enterprises, Eco-Efficiency Evaluation, Shanddong Province

1. Introduction

While giving enormous wealth to society, tradition enterprises have also brought about a series of global crisis such as resource shortage, energy crisis, environmental pollution and ecology destruction. Modern firms should be low carbon enterprises which are part of ecological system and are helpful to realize the sustainable society. So the scientific evaluation of Low Carbon Enterprises(LCE) is very important foundation for enterprises' strategies and decision-makings. This article give results for low carbon enterprises' eco-efficiency evaluation. On the one hand, AHP method can effectively turn multi-criteria decision-making problems to orderly manner problems with hierarchical structure. On the other hand, simulating the principle of human neural, ANN can identify specific problems through the study of samples. In the evaluation of low carbon enterprises' eco-efficiency, either AHP or ANN has its limitations. So the paper fixes the two methods to get the integrative effective. Researches showed that the AHP-ANN method is suitable for the assessment of low carbon enterprises' eco-efficiency.

2. Evaluation System and Criteria of Low Carbon Enterprises' Eco-efficiency

The evaluation of low carbon enterprises' eco-efficiency includes follow factors. Firstly, the evaluation includes the status, potential and coordination of the enterprise development. The evaluation departments should provide related information of eco-efficiency to decision-makers. Secondly, the evaluation includes key factors which affect the eco-efficiency. This paper uses Delphi method to complete the selection of indicators. The evaluation system of low carbon enterprises (A) is established in three aspects: development status (A_1), development potential (A_2) and development coordination (A_3).

Aspect A_1: Elements of development status, such as resources situation (A_{11}), economic situation (A_{12}), social development situation (A_{13}) , environment situation (A_{14}) and science, technology& management situation (A_{15});**Aspect A_2:** Elements of development potential, such as resource potential (A_{21}), economic potential (A_{22}), social potential (A_{23}), environmental potential impact (A_{24}) and science, technology&

management potential (A_{25});**Aspect A_3:** Elements of development coordination, such as conversion of resources (A_{31}), economic coordination (A_{32}), social coordination (A_{33}), environmental coordination (A_{34}), and science, technology& management coordination (A_{35}).

On the basis of the target hierarchy (A), guidelines hierarchy (A_1, A_2, A_3) and elements hierarch, we establish the indicators hierarchy further.

Element A_{11}: Indicators of resources situation, such as natural gas proved reserves , proven oil reserves, output of crude oil, natural gas production , portion of tertiary education and above of staff, the percent of senior staff, information development expense ratio and total population; **Element A_{12}:** Indicators of economic situation, such as margins, operating income, per capita net fixed assets, total assets and increase the amount of assets ;**Element A_{13}:** Indicators of economic situation, such as per capita income workers and children enrollment rate of workers. **Element A_{14}:** Indicators of environment situation, such as oilfield wastewater recoveryand industrial wastewater requirements; **Element A_{15}:** Indicators of science, technology& management situation, such as Million integrated energy output, the ratio of R & D funding, gas exploration mission completion rate and oil exploration mission completion rate;

Element A_{21}: Indicators of resource potential, such as gas reserves forecast, oil reserves forecast, remaining recoverable gas volume, remaining recoverable oil volume, information Inputs growth, and support resources strength; **Element A_{22}:** Indicators of economic potential, such as profit growth (A_{221}, %), revenue growth and total assets growth; **Element A_{23}:** Indicators of social potential potential, such as Per-capita funding for education workers (A_{231}, 10000 Yuan);**Element A_{24}:** Indicators of environmental potential impact, such as utilization of solid waste; **Element A_{25}:** Indicators of science, technology& management potential, such as the ratio of R & D fund for growth;

Element A_{31}: Indicators of conversion of resources, such as control gas reserves (A_{311}, billion cubic meters) and control of oil reserves; **Element A_{32}:** Indicators of economic coordination, such as annual output value of investment flexibility; **Element A_{33}:** Indicators of social coordination, such as regions employment rate; **Element A_{34}:** Indicators of environmental coordination, such as environmental protection investment of 10,000 Yuan coordination output; **Element A_{35}:** Indicators of science, technology& management coordination, such as polymerization of enterprise culture.

3. Determine the Weights of Evaluation Indicators on Low Carbon Enterprises' Sustainable Development Ability by AHP

3.1 Evaluation steps in determining the indicators' Weights

Step1: Identification of evaluation targets of low carbon enterprises, related analysis of sustainable development factors and clarification of the relationship between the factors.

Step2: Construction of evaluation hierarchical structure of low carbon enterprises' sustainable development ability. The various impact factors were divided into different hierarchies, establishing a tree structure.

Step3: Building of the judgment matrix. Experts compare the indicators with each other to reflect their relative importance hierarchy judgment score, and calculate eigenvector of judgment matrix to determine the lower indicators' contribution to the indicator in upper hierarchy.

Step4: Determine the weights of evaluation indicators. The first grade evaluation indicators are A_i (i = 1,2,3) and the weight vectors of A_i are $W = [w_1, w_2 , w_3]$. The second grade evaluation indicators are A_{1j} (j = 1,2,3,4,5), A_{2j} (j = 1,2,3,4,5) and A_{3j} (j = 1,2,3,4,5). The weight vectors of A_{1j} (j = 1,2,3,4,5) are $w_1 = [w_{11} , w_{12} , w_{13} , w_{14} , w_{15}]$, $w_2 = [w_{21} , w_{22} , w_{23} , w_{24} , w_{25}]$, $w_3 = [w_{31} , w_{32} , w_{33} , w_{34} , w_{35}]$.

Step5: Sort hierarchy calculation and consistency test. Eigenvectors are normalized by the relative importance ranking of weight of same hierarchy corresponding elements followed by the next hierarchy.

Step6: Standardization. We should change different units of indicator values' measurement into non dimensionless values. In order to facilitative narrate, we define the following settings. We let X_i (i = 1, 2,…, 39) represent for the evaluation indicator i in the third grade, and let P_i (i = 1, 2,…, 39) represent for the evaluation indicator *i*, $0 \leqq P_i \leqq 1$. We let $X_{s,i}$ ($X_{s,i} = X_{max} - X_{min}$) for the standard value of evaluation indicator *i*.

(1) For the indicators which are the higher, ①if $X_i \geqq X_{max}$, then $P_i = 1$; ②if $X_i \leqq X_{min}$, then $P_i = 0$; ③if $X_{min} < X < X_{max}$, then the formula is: $P_i = X_i - X_{min} / X_{s,i.}$

(2) For the indicators which are the lower,①if $X_i \leqq X_{max}$, then $P_i = 1$; ②if $X_i \geqq X_{min}$, then $P_i = 0$; ③if $X_{min} < X < X_{max}$, then the formula is: $P_i = X_{max} - X_i / X_{s,i.}$

3.2 Empirical analysis

It is essential to get the overall, accurate data for the empirical analysis of low carbon enterprises. The data used in the paper are provided by database of Wind consultation. They are from the 2007 annual report in the stock market of Shanghai and Shenzhen. The paper selects 11 samples of low carbon enterprises to carry on the research. The value of each index is shown in Table1. In the Table1, Ei (i=1,2,…,11) represent for low carbon enterprise.

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4.1 Essential Principles of Back-Propagation

The back-propagation algorithm is a method of training multilayer feedforward artificial neural networks. The BP artificial neural network is composed of input layer, hidden Layers and output layer. It trains study samples using gradient search method to get minimum mean square error between actual output value and expectant value value.

Table1 Samples and Weights of Each Index

Weight	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*	Weight	*E7*	*E8*	*E9*	*E10*	*E11*
A_{11}	0.06	0.19	0.12	0.21	0.22	0.25	A_{11}	0.09	0.17	0.15	0.22	0.07
A_{12}	0.07	0.31	0.22	0.10	0.28	0.34	A_{12}	0.11	0.13	0.31	0.28	0.10
A_{13}	0.12	0.34	0.17	0.12	0.31	0.37	A_{13}	0.08	0.15	0.23	0.31	0.12
A_{14}	0.09	0.27	0.15	0.09	0.26	0.28	A_{14}	0.12	0.18	0.16	0.26	0.11
A_{15}	0.18	0.46	0.27	0.33	0.65	0.53	A_{15}	0.19	0.38	0.52	0.65	0.27
A_{21}	0.20	0.28	0.15	0.19	0.21	0.36	A_{21}	0.17	0.23	0.37	0.21	0.16
A_{22}	0.17	0.25	0.19	0.22	0.24	0.41	A_{22}	0.16	0.22	0.49	0.24	0.20
A_{23}	0.13	0.26	0.20	0.17	0.26	0.35	A_{23}	0.11	0.19	0.13	0.26	0.17
A_{24}	0.07	0.29	0.14	0.25	0.34	0.32	A_{24}	0.06	0.14	0.18	0.34	0.09
A_{25}	0.18	0.42	0.23	0.16	0.39	0.59	A_{25}	0.15	0.23	0.35	0.39	0.19
A_{31}	0.09	0.25	0.16	0.13	0.24	0.27	A_{31}	0.10	0.17	0.19	0.26	0.13
A_{32}	0.11	0.31	0.17	0.16	0.20	0.24	A_{32}	0.12	0.18	0.24	0.20	0.15
A_{33}	0.14	0.17	0.20	0.22	0.27	0.23	A_{33}	0.09	0.16	0.23	0.27	0.14
A_{34}	0.11	0.25	0.14	0.17	0.33	0.28	A_{34}	0.11	0.19	0.28	0.33	0.18
A_{35}	0.16	0.53	0.30	0.29	0.45	0.62	A_{35}	0.13	0.36	0.40	0.45	0.23

The leaning course of BP is made up of two aspects forward and back propagation. In the course of forward propagation, the state in every layer only affects the next work of next neuron. If the outcomes in output layer are not the expected target, that is, the error between actual outputs and expected targets exceeds the given error, and then the course would shift to that of back propagation. During back propagation, the error signal would back track along the original path. The connective weights among every nerve cell are adjusted and the course gradually propagates to the input layer of neural network. The forward propagation would restart again. The two repeating courses would not stop until the error between actual outputs and expected targets is less than the given error.

4.2 The training of BP Artificial Neural Network

Step 1: Determine the numbers of input nodes based on the set of evaluation indicators.

Step 2: Determine the layer numbers of BP artificial neural networks. Generally speaking, we use the third layers structure of one input layer, one hidden Layers and one output layer.

Step 3: Determine the indexes' values and standardize them. These are the training samples and test samples. This paper gets these samples using AHP method which is helpful to turn multi-criteria decision-making problems to orderly manner problems with hierarchical structure.

Step4: Initialize the network state. Give random values in [0,1] to weight W_{ij} and threshold P_i .

Step5: Input training samples and calculate outputs of layers' neurons.

Step6: Calculate the weight errors of output layer by formula (1).

$$\delta_j = \left(y_j - O_j\right) O_j \left(1 - O_j\right) \tag{1}$$

Step7: Calculate the weight errors of hidden layers by formula (2).

$$\delta_j = O_j \left(1 - O_j\right) \sum_k W_{ij} \delta_k \tag{2}$$

Step8: Calculate the correction weight errors by formula (3).

$$\Delta W_{ij}(n) = -\eta \delta_j O_j + \alpha W_{ij}(n-1) \tag{3}$$

Step9: Correct weights by formula (4).

$$W_{ij}(n+1) = W_{ij}(n) + \Delta W_{ij}(n) \tag{4}$$

Step10: Input other samples, return to the step5 until network converges and output error is less than allow value.

4.3 Results of low carbon enterprises' Assessment

On the basis of samples and weights of each index by AHP, as Table1 shows, we do further works by the BP network. Firstly, we train the BP network through the train samples (from 1^{st} to 6^{th} low carbon enterprises in Shandong Province). Secondly, we test the assessment of the AHP and ANN comprehensive assessment model by the test samples (from 7^{th} to 11^{th} low carbon enterprises in Shandong Province).In the research, number of hidden layer' node is defined to 5. Weight adjust parameter is defined to 1. Threshold adjust parameter is defined to 0.1.Through 4000 times training, the network converges and output error is less than allow value. The test result is shown in Table 2. In Table2, "Ac-output" means Actual Output; "An-output" means Anticipant Output; "Error" means the Relative Error; "Tr-Sequence" means Trains Sequence; and "Ex-Sequence" means Experts' Sequence.

Table2 Test Results and Sequences of Low Carbon Enterprises

Enterprise	E7	E8	E9	E10	E11
Ac-Output	0.35	0.55	0.75	0.79	0.46
An-Output	0.35	0.55	0.75	0.79	0.46
Error (%)	0.39	0.22	0.15	0.30	0
Tr-Sequence	5	3	2	1	4
Ex-Sequenc	5	3	2	1	4

From the Table2, we can see that the maximum relative error of actual output and Anticipant output is less than 0.39%. The trains sequence is consistent with the experts' sequence. It is shown that the AHP and ANN comprehensive assessment model is suitable to assess the low carbon enterprises' sustainable development ability.

5. Conclusion

In the evaluation of low carbon enterprises' eco-efficiency, either AHP or ANN has its disadvantage. The paper fixes the two methods to complement them. Firstly, the method keeps the merits of AHP method. It can receive the sort of superiors and inferiors which reflects people's experience of problems. Secondly, the method keeps strong points of ANN method. It has good correction, self-adaptation and self-organization. Thirdly, comparing with traditional methods, the research is closer to reality, and is easy to be promoted. Research shows that the synthetically method is a useful approach which can fully absorb experts' experience and effectively use enterprises' actual data. Obviously, the compositive method is suitable for the assessment of low carbon enterprises. And it is recommendable to analogous problems.

References

[1]. J. A. Aragon-correa, S. A. Sharma. Resource-based View of Proactive Corporate Environmental Strategy. Academy of Management Review, 1(2003), p 71～88.

[2]. R.Nidumolu. Why Sustainability is Now the Key Driver of Innovation. Harvard Business Review,9(2009),p56～64.

[3]. J. Lin; Y. Li; W. Wang. An eco-efficiency-based sustainability assessment method and its application. International Journal of Sustainable Development & World Ecology, 8(2010) , p356～361.

[4]. Robert J., Graeme C., John B. Application of partial mutual information variable selection to ANN forecasting of water quality in water distribution systems. Environmental Modelling & Software,10(2008) ,p1289～1299.

[5]. Kenzheguzin M B, Yessekina B K. Methodological Basis of Forecasting of Sustainable Development of Economic System. Mathematics and Computers in Simulation,5(2006) ,p343～349.

[6]. Cebeci, Ufuk, Ruan. A Multi-attribute Comparisonof Turkish Quality Consultants by Fuzzy AHP. International Journal of Information Technology & Decision Making,1(2007) ,p191～207.

[7]. Hezri A Adnan, Hasan M Nordin. Management Framework for Sustainable Development Indicators in the State of Selangor Malaysia. Ecological Indicators,4(2008) ,p287～304.