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Comprehensive Evaluation Method and Management of Green Economy Development of Large Chemical Enterprises

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The chemical industry is a basic industry closely related to the national economy and people's livelihood, and the analysis and evaluation of its economic development model has significant practical significance. Based on the analytic hierarchy process (AHP), this paper establishes a set of evaluation indicator system for the green economy development of large chemical enterprises, and it uses examples to evaluate the development level of green economy of a large chemical enterprise. The results show that the established green economy development level evaluation system of large chemical enterprises considered the impact of various influencing factors on the green economy development of chemical enterprises, and it is beneficial for the balance of the steady state relations among economy, environment, resources and other aspects, so as to realize the mode of green economy development of chemical enterprises; the comprehensive index of the evaluation indicator system of green economy development of a large chemical enterprise is 0.423, indicating that the green economy development level of this chemical enterprise is at a medium level, and it still needs further optimization to improve its green economy development mode.

1. Introduction

The development of China's coal industry and petroleum industry has promoted the rapid growth of the national economy and made great contributions to social development and national economy and people's livelihood (Huang, 2010; Chen and Fang, 2015). However, there are still non-ignorable problems in the development process of coal industry, petroleum industry and chemical industry, such as low oil storage, uneven distribution, low coal recovery rate, low conversion utilization rate, and the coal mining is quite harmful to the environment (Marchiol and Fellet, 2011; Aryal et al., 2015; Chen and Hsieh, 2010). Therefore, in today's society which is under great ecological pressure and short in energy, combining the low-carbon economy with the circular economy, introducing green economy development into chemical enterprises, and constructing and optimizing the green economy development mode of chemical enterprises is of significant social value and theoretical significance for the full utilization of chemical resources and reduction of ecological environment pollution.

The green economy development system is an economy development form which takes the environment improvement as a fundamental condition, and this kind of economy development form requires enterprises including chemical enterprises to make full use of the green technology system in the production and operation process (Montmassonclair, 2016; Novoselov et al., 2017). The above-mentioned green technology system is a collection of environmentally-friendly technologies such as energy conservation and emission reduction, ecological environment improvement and optimization, and it is a dynamic technology system formed by the interaction of professional knowledge, technical means, materials and capabilities (Yen, 2015; Bu et al., 2010). The development of green economy effectively combines circular economy with the low-carbon economy to form a new type of sustainable economic growth model (Saliba, 2017; Götz and Schäffler, 2015). In order to rationally develop chemical enterprises on the basis of protecting ecological balance, this paper establishes a set of evaluation indicator system for the green economy development of chemical enterprises based on green economy theory, it comprehensively evaluates and analyzes the economy development of large chemical enterprises, and provides a theoretical guidance for the development of green economy of chemical enterprises.

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2. Green economy development system

2.1 Green economy evaluation standard

For the development level of the green economy of large chemical enterprises, this paper divides it into five grades. As shown in Table 1, the closer the score of green economic development level is to 1, the higher the level of green economic development of chemical enterprises is, otherwise, it indicates that the enterprise's economy development is poor.

Table 1: Division of green economy development level in chemical enterprises

Level of development	1	2	3	4	5
Grade score interval	(0.8, 1]	(0.6, 0.8]	(0.4, 0.6]	(0.2, 0.4]	(0, 0.2]
Development level of green economy	Very high	High	Intermediate	Lower	Very low

2.2 Indicator weights for the level of green economy development of chemical enterprises

In order to determine the hierarchical structure of green economy development of chemical enterprises, first, this paper uses AHP to decompose the problem into four layers (target layer, standard layer, index layer and scheme layer) as shown in Figure 1.

Then, targeting on the problem of the green economy development of large chemical enterprises, a corresponding judgment matrix is constructed to represent the relative importance of an element in the upper layer to the elements in the immediate lower layer, while in the standard layer, the element with lower-layer subordination relationship is the first element of the established judgment matrix of the green economy development level. The established judgment matrix is shown as Table 2.

For the judgment matrix results, the assignment is based on the degree of importance between the factors, as shown in Table 3.

Based on the above judgment matrix, the relative weights of the elements are calculated by the sum method. For an inconsistent judgment matrix, the weights of vectors in each column were calculated according to Equation 1, while for a consistent judgment matrix, the corresponding weights can by obtained by normalizing vectors in each column.

Assuming that the judgment matrix is as shown in Equation 2, the steps of calculating the relative weights of each element according to the sum method are as shown in Equations 3 to 7.

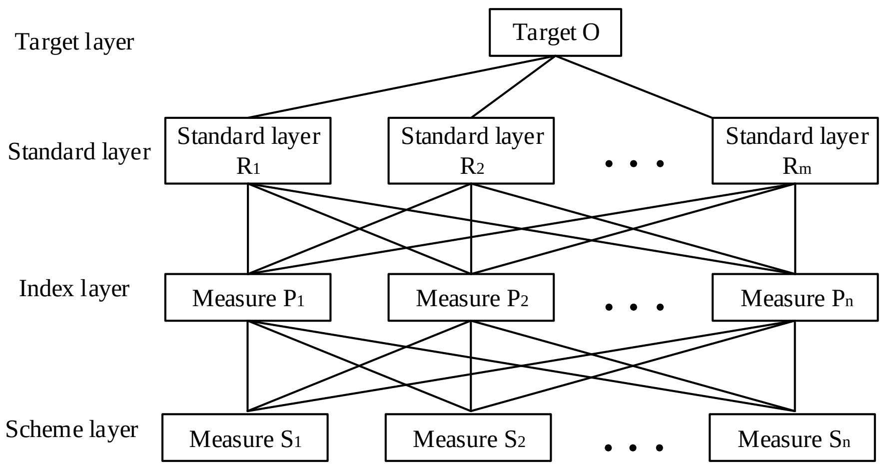

Figure 1: Model structure of AHP for green economy development

Table 2: The judgement matrix of green economy development level

M_x	N_1	N_2	N_3	N_4
N_1	n_{11}	n_{12}	n_{13}	n_{14}
N_2	n_{21}	n_{22}	n_{23}	n_{24}
N_3	n_{31}	n_{32}	n_{33}	n_{34}
N_4	n_{41}	n_{42}	n_{43}	n_{44}

Table 3: The implication of importance assignment scale

Assignment scale	Implication
1	The two elements are equally important
3	The former is slightly more important than the latter
5	The former is obviously more important than the latter
7	The former is strongly more important than the latter
9	The former is extremely more important than the latter
2, 4, 6, 8	The intermediate value of the above judgment
Reciprocal	If the ratio of importance between elements I and j is m_{ij}, the ratio of importance between elements J and I is m_{ij} =1/ m_{ji}

$$W_i = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{ij}}{\sum_{k=1}^{n} a_{ki}} \tag{1}$$

$$A = \left(b_{ij}\right)_{nn} \tag{2}$$

$$\overline{b_{ij}} = \frac{b_{ij}}{\sum_{k=1}^{n} b_{kj}}, \quad (i,\ j\text{=1, 2, ..., n}) \tag{3}$$

$$\overline{W_1} - \sum_{j=1}^{n}\overline{b_{ij}},\ (j\text{=1, 2, ..., n}) \tag{4}$$

Normalize vector $\overline{W} = (\overline{W_1}, \overline{W_2}, \ldots.., \overline{W_n})^T$ to get:

$$\overline{W} = \frac{\overline{W_i}}{\sum_{j=1}^{n} W_j}, \quad (i\text{=1, 2, ..., n}) \tag{5}$$

Then, the maximum eigenvalue of the judgment matrix is:

$$\lambda_{\max} = \sum_{i=1}^{n}\frac{\left(AW\right)_i}{nW_i} \tag{6}$$

$(AW)_i$ is the i-th element of the vector AW, then there is:

$$\lambda_{\max} = \frac{\left(AW\right)_i}{W_i} \quad \left(i = 1, 2, \ldots, n\right) \tag{7}$$

Where a_{ij} is an element in the judgment matrix A, b_{ij} is the importance scale of the elements B_i and B_j with respect to matrix A, and $(W_1, W_2, ..., W_n)^T$ is the relative weight vector of A with respect to elements B_1, B_2,…B_n.

After calculating the relative weights of the elements, it is necessary to test the consistency of the judgment matrix. The specific steps are as follows: Calculate the consistency index *C.I.* according to Equation 8, then determine the average random consistency index *R.I.* referring to Table 4. According to Equation 9, the consistency index and the average random consistency index are used to calculate the consistency ratio *C.R.*, thereby determining the consistency of the judgment matrix. When the value of *C.R.* is less than 0.1, the judgment matrix is considered to meet the consistency requirement. Otherwise, it is considered that the consistency requirement is not met, and the judgment matrix needs to be corrected.

$$C.I. = \frac{\lambda_{\max} - n}{n - 1} \tag{8}$$

$$C.R. = \frac{C.I.}{R.I.} \tag{9}$$

Table 4: Random consistency indicators

Order of matrix	1	2	3	4	5	6	7	8
R.I.	0	0	0.52	0.89	1.12	1.26	1.36	1.41
Order of matrix	9	10	11	12	13	14	15	-
R.I.	1.46	1.49	1.52	1.54	1.56	1.58	1.59	-

Finally, perform the final step of AHP—hierarchy total ranking, similar to the above, from top to bottom, layer by layer, calculate the weight of each factor in each layer with respect to the factors in the upper layer, ranking according to the weight, and then perform consistency check of the total ranking according to equation 10. If the $C.R.^{(m+1)}$ of the total elements of the (m+1) layer is less than 0.1, the total ranking is consistent with the consistency check, otherwise it is considered to be inconsistent with the consistency check.

$$C.R.^{(m+1)} = \frac{C.I.^{(m+1)}}{R.I.^{(m+1)}} \tag{10}$$

In the above equation:

$$C.R._j^{(m+1)} = \left(C.R._1^{(m+1)}, C.R._2^{(m+1)}, ..., C.R._n^{(m+1)}\right)W^m \tag{11}$$

$$R.I._j^{(m+1)} = \left(R.I._1^{(m+1)}, R.I._2^{(m+1)}, ..., R.I._n^{(m+1)}\right)W^m \tag{12}$$

Based on AHP, according to the above steps, the weight of the green economy development level of large chemical enterprises can be calculated and comprehensively analyzed and evaluated.

3. Evaluation indicator system for green economy development of a large chemical enterprise

According to the evaluation indicator system for green economy development of enterprises, the evaluation indicator system for green economy development of a large chemical enterprise is divided into three layers: target layer A, standard layer B and variable layer C. The stratification and influencing factors of the system are shown as Figure 2. In this paper, the judgment matrix is established by scoring data from questionnaires filled out by 10 experts, and the relative weights of each factor are calculated. The calculation results are shown in Table 5~Table 8.

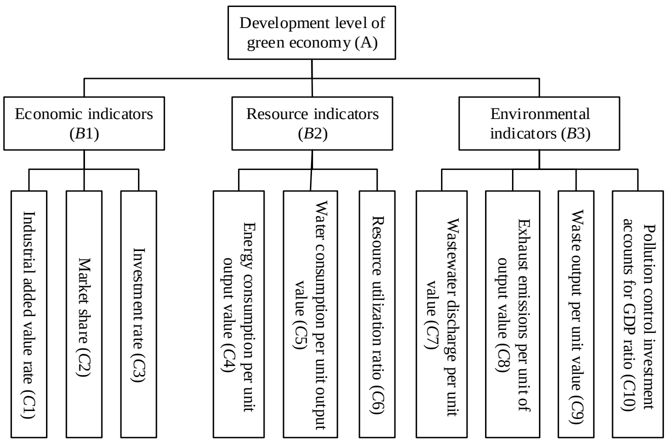

Figure 2: Evaluation indicator system for green economy development of a large chemical enterprise

Table 5: Judgment matrix of A-B

A	B_1	B_2	B_3	*w*	$\lambda_{max} = \mathbf{3.005}$
B_1	1	2	1/3	0.230	C.I.=0.0025
B_2	1/2	1	1/5	0.122	C.R.=0.004 < 0.1
B_3	3	5	1	0.648	(General agreement)

Table 6: Judgment matrix of B_1-C

B_1	C_1	C_2	C_3	w	$\lambda_{max} = \mathbf{3.074}$
C_1	1	4	4	0.601	C.I.=0.037
C_2	1/3	1	3	0.277	C.R.=0.071 < 0.1
C_3	1/4	1/3	1	0.122	(General agreement)

Table 7: Judgment matrix of B_2-C

B_2	C_4	C_5	C_6	*w*	$\lambda_{max} = \mathbf{3.021}$
C_4	1	1/2	3	0.320	C.I.=0.011
C_5	2	1	4	0.557	C.R.=0.02 < 0.1
C_6	1/3	1/4	1	0.127	(General agreement)

Table 7: Judgment matrix of B_3-C

B_3	C_7	C_8	C_9	C_{10}	*w*	
C_7	1	2	3	5	0.456	$\lambda_{max} = \mathbf{4.113}$
C_8	1/2	1	3	5	0.324	C.I.=0.038
C_9	1/3	1/3	1	3	0.152	C.R.=0.042 < 0.1
C_{10}	1/5	1/5	1/3	1	0.068	(General agreement)

Secondly, calculate the *C.R.* value of the total ranking of the hierarchy and perform consistency test, there is *C.R.*=0.036<0.1, so the total ranking conforms to the consistency test. Finally, perform weighted calculation to indicators in all layers, we can get that the comprehensive index of the green economy development evaluation indicator system of the large chemical enterprise is 0.423. By looking up Table 1 we can know that, this chemical enterprise's green economy development level is at a medium level.

4. Conclusion

Based on AHP, this paper analyzed and calculated the weights of various indicators affecting the development of green economy of large chemical enterprises, and established an evaluation indicator system for green economy development of chemical enterprises, and then it comprehensively evaluated and systematically analyzed the green economy development of large chemical enterprises. The main conclusions of this paper are as follows:

(1) Based on AHP, a set of index evaluation system suitable for the development level of green economy of large chemical enterprises has been established, which has great theoretical guiding significance and application value.

(2) This paper took economic indicators, resource indicators and environmental indicators as evaluation indicators for the development of green economy of large chemical enterprises, it comprehensively considered the impact of various influencing factors on the green economy development of chemical enterprises with excellent logic and rationality.

(3) Through AHP and weighted calculation of the evaluation indicators in all layers, this paper concluded that the comprehensive index of the green economy development evaluation indicator system of a large chemical enterprise is 0.423, indicating that the green economy development level of the chemical enterprise is at a medium level.

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