Evaluation and Grading Model of Building Materials Suppliers Considering Low-carbon Factors

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Abstract. This paper establishes the evaluation index system of building materials suppliers from five aspects about economy, quality, technology, supply and greenness, and takes greenness as a main measure. The fuzzy comprehensive analysis method is used to determine the weight of each index. Then through the established supplier scoring system to score the suppliers and grade them according to the scores, so that the company can manage many suppliers conveniently.

1. Introduction

Since the industrial revolution, the global economy and society have developed rapidly. The endless demand and utilization of natural resources have led to a sharp rise in carbon emissions, which has directly triggered global climate problems. How to control carbon emissions and slow down the greenhouse effect has become one of the hot topics of international community [1-2]. Under the low-carbon background, contribution of enterprises to the development of green economy is very huge. As a high-energy and high-emissions industry, reduce the carbon emissions generated by building materials could achieve a virtuous cycle of development between the enterprise and the environment. Carbon emissions in the control area and even in the world have a positive impact [3].

Under the general trend of global emission reduction, enterprises must pay attention to the use of green building materials in order to obtain long-term economic effects. In the case of a highly developed modern market economy, the number of suppliers is large and diverse. Choosing the most suitable supplier among a wide range of suppliers can be achieved by establishing an indicator system that suits current trends [4]. In the supplier indicator system, the first to start researching is Dickson G.W. [5]. The traditional supplier evaluation indexes mainly include quality, price, delivery, etc. Under the trend of advocating global emission reduction, this paper establishes a set of green degree as the main indicator based on the traditional supplier evaluation system. According to the evaluation system of building materials suppliers, a supplier grading system is constructed to facilitate the better management of suppliers.

2. Suppliers' grading model

2.1. Evaluation Index System for Building Suppliers in the Low-carbon Environment

Based on the results of relevant literature, this paper combines current development trends of the construction industry with the green degree background. Also it combines traditional evaluation indicators about suppliers with greenness indicators which are economy, quality, supply, and green.

Invite the experts and managers of the enterprise to determine the evaluation indicators according to the environment in which the current enterprise is located, and construct a hierarchical structure model of the supplier evaluation. The target layer is the optimal supplier; the second layer is the middle layer 1, which is the element for evaluating the supplier; the third layer is the middle layer 2, which is the subdivision of each element of the second layer; the last layer is at the solution level, the solution layer is all the suppliers considered by the enterprise. The indicator system is shown in Table 1 below:

Table 1.Supplier evaluation index system

primary index	secondary index	Tertiary index	scoring standards
Supplier Evaluation A	Economic index B1	Price Level C1	Minimum bid score 100,other suppliers score inversely proportional to the minimum bid
		Quotation behavior C2	expert score
		Cost reduction measures C3	expert score
		Payment C4	expert score
	Quality index B2	Quality pass rate C5	$\frac{Quality\ qualified\ quantity}{Total\ quantity\ supplied} \times 100$
		Quality Assurance System C6	expert score
		Product exemption rate C7	$\frac{Exempted\ product\ quantityn}{Total\ number\ of\ products} \times 100$
	Technical indexB3	technical skills C8	expert score
		Equipment and technology C9	expert score
	Supply indexB4	On-time delivery rate C10	$\frac{The\ actual\ batch\ delivered\ on\ time}{The\ batch\ of\ total\ delivery} \times 100$
		Production cycle C11	expert score
		Order change acceptance rate C12	$\frac{Order\ quantity\ change}{Original\ order\ quantity} \times 100$
	Green degree		show in Table 2

Table 2. Greenness indicator score standard

score	Description
90-100	The product design meets the requirements of low carbon, the product meets the requirements of the relevant environmental management system, and there are energy saving and emission reduction measures in the production process, and the product can be recycled and remanufactured.
80-90	The above one is not completed
70-80	The above two are not completed
60-70	The above three items are not completed
0-60	The above four items are not completed

2.2. Use the fuzzy comprehensive analysis method to determine weight

2.2.1. Constructing fuzzy consistent judgment matrix

(1) Scale selection

In order to make a quantitative comparison between the two indicators of their importance, this paper selects the scale of the quantitative measurement according to the 0.1-0.9 scale method in Table 3.

Table 3. Quantity scale of 0.1-0.9

Scale	description
0.5	Equal importance of "i" and "j"
0.6	Weak importance of "i" over "j"
0.7	Strong importance of "i" over "j"
0.8	Demonstrated importance of "i" over "j"
0.9	Absolute importance of "i" over "j"
0.1,0.2 0.3,0.4	R_{ij} is determined by comparison of element c_i and element c_j, and $r_{ji} = 1 - r_{ij}$ is determined by comparison of element c_j and element c_i

(2) Establish a judgment matrix

In the fuzzy analytic hierarchy process, there is a series relationship in indicators. When constructing the judgment matrix, we need to establish a judgment matrix for multiple levels of indicators. Then, ask relevant experts of the enterprise and the core management personnel of each department to form a team, have a meeting to score each index, compare the indicators in pairs, using the above scale and the weighted average method to calculate the final score in order to establish the judgment matrix [6].

(3) Matrix consistency test

According to the method of fuzzy complementary matrix consistency test, namely the difference between an arbitrarily designated row of the fuzzy complementary matrix $R = (r_{ij})_{n\times n}$ and the corresponding elements of the remaining rows is a certain constant, in order to test the fuzzy consistency of the above judgment matrix.

2.2.2. Calculate the weight of each factor in the target with the AHP

Calculate the relative weight of the elements under a single criterion. The first step is to calculate the product M_i of each row element of the fuzzy uniform matrix, and then find its n-th root whose n is determined by the order of the matrix. So there comes$\overline{W_n} = \sqrt[n]{M}$. After that, use the formula $Wn = \frac{\overline{Wn}}{\sum_{i=1}^{n}\overline{Wn}}$ to normalize vector, and elements in the eigenvector arerelative weights of the elements under a single criterion.

2.3. Suppliers' grading standards

The supplier is graded according to their scores and specific grading standards are as follow;

Class A: 90-100 points; Class B: 80-89.99 points; Class C: 70-79.99 points; Class D: 70 points or less

According to the results of each rating, different measures are taken for suppliers:

(1) Class A suppliers: The products and services of this type are very beneficial to the company. When the company has new product requirements, it can give suppliers priority to quotations. It is suitable for company to establish long-term strategic partnership with such suppliers;

(2) Class B suppliers: the products and services of this type are relatively beneficial to the enterprise, and it can be used as a backup supplement for the A-level supplier when the company has new product demands;

(3) Class C suppliers: the products and services of such suppliers remain elusive. When there is a sufficient number of suppliers at both A and B levels, the company should stop inquiring about new products from the C level;

(4) Class D suppliers: companies should immediately stop cooperation with such suppliers.

3. Numerical example of Supplier grading system

3.1. Determine evaluation indicator weights

(1) Establish the hierarchical structure model: according to the building material supplier evaluation index system shown in table 1, establish the evaluation indexes for three alternative suppliers.

(2) Constructing a fuzzy consistent judgment matrix: according to the previously established evaluation method, the relative importance of the indicators of the indicator system is compared, and the following five matrices are obtained:

$$R_A = \begin{bmatrix} 0.5 & 0.4 & 0.7 & 0.6 & 0.4 \\ 0.6 & 0.5 & 0.8 & 0.6 & 0.4 \\ 0.3 & 0.2 & 0.5 & 0.4 & 0.1 \\ 0.4 & 0.4 & 0.6 & 0.5 & 0.3 \\ 0.6 & 0.6 & 0.9 & 0.7 & 0.5 \end{bmatrix}$$

$$R_{B1} = \begin{bmatrix} 0.5 & 0.6 & 0.9 & 0.7 \\ 0.4 & 0.5 & 0.8 & 0.6 \\ 0.1 & 0.2 & 0.5 & 0.3 \\ 0.3 & 0.4 & 0.7 & 0.5 \end{bmatrix}$$

$$R_{B2} = \begin{bmatrix} 0.5 & 0.7 & 0.8 \\ 0.3 & 0.5 & 0.6 \\ 0.2 & 0.4 & 0.5 \end{bmatrix}$$

$$R_{B3} = \begin{bmatrix} 0.5 & 0.6 \\ 0.4 & 0.5 \end{bmatrix}$$

$$R_{B4} = \begin{bmatrix} 0.5 & 0.6 & 0.8 \\ 0.4 & 0.5 & 0.7 \\ 0.2 & 0.3 & 0.5 \end{bmatrix}$$

(3) Consistency test

According to the above test method, the consistency test is performed on the matrix, and the difference between the corresponding elements of the first row and the second row in the B1 judgment matrix is: $r_{1k} - r_{2k} = 0.1(k = 1,2,3,4)$. This value is a constant. It explains that the matrix is consistent. By analogy, other matrices have also passed the consistency test.

(4) Index weight calculation

Using the square root method described above, the weight vector of the R_A matrix can be obtained as: $\omega_0 = (0.2106,0.2346,0.1082,0.1178,0.2686)^T$. Similarly, the weight vectors of theR_{B1}, R_{B2}, R_{B3} and R_{B4} matrices can be found as: $\omega_1 = (0.3465,0.2925,0.1230,0.2380)^T, \omega_2 = (0.4626,0.3168,0.2418)^T, \omega_3 = (0.5505,0.4494)^T, \omega_4 = (0.4282,0.5377,0.2141)^T$.

(5) Determine the total weight of the indicator

According to the results of the single hierarchical order obtained, the total hierarchical order is calculated. The weights of the supplier evaluation system are summarized in Table 4.

Table 4. Summary table of supplier evaluation index weight

Secondary index	weight	Tertiary index	Single weight	Total weight
Economic index	0.2106	Price Level	0.3465	0.0730
		Quotation behavior	0.2925	0.0616
		Cost reduction measures	0.1230	0.0259
		Payment	0.2380	0.0501
Quality index	0.2346	Quality pass rate	0.4282	0.1005
		Quality Assurance System	0.3168	0.0743
		Product exemption rate	0.2418	0.0567
Technical index	0.1082	technical skills	0.5505	0.0596
		Equipment and technology	0.4494	0.0486
Supply index	0.1178	On-time delivery rate	0.4282	0.0504
		Production cycle	0.5377	0.0633
		Order change acceptance rate	0.2141	0.0252

Green degree	0.2686	0.2686

3.2. Score statistics

A construction company needs suppliers to provide a batch of new building materials, and collects data from suppliers on the evaluation indicators after inquiry. The results are summarized in the following table 5:

Table 5. Summary of supplier grading scores

secondary index	Tertiary index	Total weight	X single score	X score	Y single score	Y score	Z single score	Z score
B1	C1	0.0730	100	7.30	90	6.57	80	5.84
	C2	0.0616	100	6.16	100	6.16	50	3.18
	C3	0.0259	88	2.80	96	2.49	76	1.97
B2	C4	0.0501	100	5.01	98	4.91	96	4.81
	C5	0.1005	96	9.65	98	9.85	78	7.83
	C6	0.0743	100	7.43	100	7.43	75	5.57
	C7	0.0567	96	5.44	90	5.10	85	4.82
B3	C8	0.0596	75	4.47	100	5.96	75	4.47
	C9	0.0486	100	4.86	75	3.65	50	2.43
B4	C10	0.0504	86	4.33	90	4.53	95	4.80
	C11	0.0633	85	5.38	92	5.82	90	5.70
	C12	0.0252	95	2.39	94	2.37	85	2.14
B5		0.2686	85	22.83	95	25.52	80	21.49

3.3. Effectiveness analysis

The final score is: supplier X: 88.05, supplier Y: 90.36, supplier Z: 75.05. According to supplier grading standard supplier X is classified as B, supplier Y is classified as A, and supplier Z is classified as C. It can be seen that the new supplier grading model is conducive to more comprehensive display of the supplier's performance in terms of green degree, in low carbon under the background of the times. The system of adding green degree indicator is more scientific and perfect, which helps suppliers to realize their shortcomings. This system can cause suppliers to pay attention to green degree. Let them continue to improve, and build environmentally friendly enterprises.

4. Conclusion

In the case of rapid economic development, the construction industry as a huge energy-consuming industry has brought huge challenges to the ecosystem. In the low carbon background, enterprises should actively advance the green economy and rationally plan the development of enterprises. It can be seen from the numerical example that the characteristics of this paper are the addition of green degree index to the traditional supplier evaluation system. Using fuzzy analytic hierarchy process to calculate the weights and score and grade the suppliers. It has a very high practicality for the evaluation and grading of construction materials suppliers under low carbon background.

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