Research of the Selection of Green Material Suppliers Based on Entropy- TOPSIS Model

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Abstract. The construction industry must change the traditional extensive mode of production and take the sustainable development road. The promotion of green supply chain in the construction industry is conducive to improving the high consumption of resources, serious environmental pollution, and beneficial to the realization of green building. In the meanwhile, choosing a suitable supplier is a key to ensure that the green supply chain operates effectively. Therefore, according to the characteristics of green material suppliers, this paper establishes the evaluation indicator system of green material suppliers from the following three aspects: product level, enterprise status and green level, and then constructs the green material supplier selection model with Entropy Weight method and TOPSIS method. Finally, this paper carries out empirical research to test the effectiveness of the model.

1. Introduction
As a pillar industry of the national economy, the China's construction industry has made a great contribution to GDP directly or indirectly, but the high level of resource consumption and the construction environment pollution have become serious problems. Studies shows that China's construction industry consumes 25-30% of the total resources and the annual output of construction waste accounts for 1/3 of the total urban garbage [1]. Therefore, the construction industry needs to change the traditional way of construction, pay more attention to the new-type construction model with green building as its core and take the sustainable development path. At present, the central and local government departments have introduced policies to promote the implementation of green buildings. However, these documents mainly focus on the architectural aspects, such as green buildings, green building evaluation system, etc., and ignore the role of participants in the formation of green buildings. So, this paper examines this problem from the perspective of the supply chain, combining the traditional building supply chain with the green building concept to redesign the traditional building supply chain into a new green building supply chain. The building material supplier is the fundamental of this new building supply chain, and its green awareness and behavior combine with the cooperation between different participants can achieve the green building industry. So how to choose the green material suppliers becomes the subject of this study.

The reminder of the paper is organized as follows. Section 2 states the theories of green supply chain and supplier selection. Section 3 describes the establishment of the evaluation indicator system and the model of green material supplier selection, and adds the usages of the Entropy method and TOPSIS.
Section 4 provides the application of the model. Section 5 presents the conclusion and the necessary improvement for future study.

2. Theories of green supply chain and supplier selection

The green supply chain concept was first introduced in the 1970s for the study of green procurement. In 1996, Michigan State University put forward the clear concept of green supply chain for the first time [2]. From then on, an increasing number of researchers began their studies on green supply chain. Berman considered that the impact of the environment should be cared when built supply chain model. Also, he analyzed the similarities and differences between the traditional supply chains and the green supply chain, and explained the problems that will arise in the operation of the green supply chain [3]. Wang Zhu explored issues such as product design in green supply chains and classified green products [4]. Kazim proposed a novel decision framework to evaluate green supply chain management and the framework is developed by combining Monte Carlo simulation, AHP and VIKOR methods under fuzzy environment [5].

Supplier selection is a comprehensive, objective and systematic assessment of the overall performance of the supplier or retailer on the supply chain. Through the comprehensive assessment of suppliers' quality and Safety, technical level, delivery service, cost price and management level, purchasers select the enterprise strategic partners to ensure that the product quality effectively and reduce the risk brought by the supplier. The existing literatures mainly focus on the evaluation of suppliers from the evaluation indicator system and the evaluation model, for example, Li Ming used AHP method and TOPSIS to compare the multiple suppliers [6]; Wang Xu Bin used gray correlation analysis for supplier selection [7].Shen put out multi-indicators, fuzzy set theory to evaluate the supplier [8]. Dursun introduced the quality function expansion method and fuzzy weighted average method to select the suppliers [9]. R. J. Kuo established ANN-MADA evaluation model by combining artificial neural network (ANN) with two multi-attribute decision analysis (MADA) methods, and comprehensively considered the traditional supplier evaluation factors and environmental factors [10]. All those studies have enriched the theoretical research of green supply chain and supplier selection, and have great practical significance. However, few scholars have studied the selection of green material suppliers in the construction industry, especially from the criteria of the green attribute of the product. In order to make up for this deficiency, this paper combines the Entropy method with the TOPSIS to establish the green material supplier green materials suppliers.

3. Establishment of the green material supplier model

3.1. Establishment of the evaluation indicator system

The choice of green material suppliers is essentially a multi-objective decision-making problem. There are many evaluation indicators involved in the selection of green material suppliers, including the general characteristics of the product, the business situation, the relationship between the owner and the supplier, the green level of the product [11]. Constructing a sound and reasonable indicator system is the core issue for the selection of green building suppliers. In order to ensure that the indicator system can reflect the situation of suppliers comprehensively, objectively and truthfully, the procedure of building evaluation indicator system must comply with the following principles: scientific system principle, qualitative and quantitative combination principle and index comparability principle etc. Considering the previous studies, this paper establishes the evaluation indicator system of green material suppliers, as shown in Fig.1. Qualitative indicators, like $A_{12}, A_{21}, A_{22}, A_{23}, A_{32}, A_{33}$, are determined by experts, who give each indicator score of different suppliers according to their actual situation. The score is divided into 1-10 points, 1 represents the performance of the indicator while 10 represents the best.
3.2. Construction of green material supplier selection model based on Entropy method - TOPSIS

3.2.1. Determine the weight of each indicator. In order to reduce the influence of subjective factors on the weight of indicators, the Entropy method is adopted to determine the objective weight and to get a comprehensive and objective evaluation.

Entropy method: Entropy is the concept of thermodynamics, and shows the degree of system disorder. In 1948, Shennong introduced entropy into the information field and founded the information theory. The higher system order degree, the more information contained, the smaller the entropy, or else the entropy is bigger. Therefore, the smaller the information entropy of an index, the greater the degree of variation of the index value, the greater the amount of information provided, the greater the weight of the index; otherwise, the greater the index information entropy, the smaller the degree of variation of the index value, the smaller the amount of information, the smaller the weight of the index. Supposing that there are m alternatives and an evaluation indexes, and the evaluation index values of each option form a multi-objective decision matrix $X$, $X_{ij}$ is the index value of the jth index of the I option, and the weighting process is as follows:
\[ Y_{ij} = \begin{cases} x_{ij} & \text{if positive indicator:} \\ 1 - \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} & \text{if negative indicator:} \end{cases} \]

- The entropy of item j can be defined as:
  \[ H_j = -K \sum_{i=1}^{m} y_{ij} \ln y_{ij} \quad (j = 1, 2, ..., n) \]
  where \( K = \frac{1}{\ln n} \)

Set the indicator weight \( w_j \),

\[ w_i = \frac{h_j}{\sum_{j=1}^{n} h_j} \]

3.2.2. Constructing green material supplier selection model based on TOPSIS. TOPSIS is also called approximation ideal solution ordering method, which is a common method for multi-objective decision analysis of finite solution in system engineering, proposed by Wang. C. L and Yoon. K. S in 1981. The basic idea of TOPSIS to solve the problem is to calculate the distance of evaluation object to the ideal solution and negative ideal solution, according to the results, sorting the evaluation objective. The optimization alternatives should be as close to ideal solution as possible, and as far away from the negative ideal solution as possible. The ideal solution is a fictional optimal solution, and each attribute is the best value of the attribute in the decision matrix. On the contrary, the negative ideal solution is the worst solution of fiction. Each of its attribute values is the worst value of each indicator in the evaluation object. The calculation process as follow:

Construct an Initialization Decision Matrix: The decision matrix X of each alternative can be expressed as:

\[ X = \begin{pmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{nm} \end{pmatrix} \quad (1) \]

Dimensionless decision matrix: because the dimensions of each evaluation index are different, the initial value is not comparable, so the dimension of the index should be dimensionless, and the constructed dimensionless decision matrix can be expressed as:

\[ Y_{ij} = \left( y_{ij} \right)_{\text{max}} \]

- Construct the weighted decision matrix: the entropy method is used to determine the weight of each evaluation index \( w_j \), and the weighted decision matrix can be expressed as:

\[ V_{ij} = \left( v_{ij} \right)_{\text{max}} \]

So,

\[ V_{ij} = \begin{pmatrix} w_{1}y_{i1} & \cdots & w_{n}y_{in} \\ \vdots & \ddots & \vdots \\ w_{1}y_{im} & \cdots & w_{n}y_{mn} \end{pmatrix} \quad (2) \]

- Determine the set of ideal solution \( V^+ \) and negative solution \( V^- \):
\[ V^+ = \begin{cases} \max v_{ij} \ (i = 1, 2, \ldots, m; \ j = 1, 2, \ldots, n) & \text{for the positive indicator} \\ \min v_{ij} \ (i = 1, 2, \ldots, m; \ j = 1, 2, \ldots, n) & \text{for the negative indicator} \end{cases} \]  

\[ V^- = \begin{cases} \min v_{ij} \ (i = 1, 2, \ldots, m; \ j = 1, 2, \ldots, n) & \text{for the positive indicator} \\ \max v_{ij} \ (i = 1, 2, \ldots, m; \ j = 1, 2, \ldots, n) & \text{for the negative indicator} \end{cases} \]  

(3)

- Calculate the distance between the program and the ideal solution set, \( D^*_i \), and the negative ideal solution set \( D^-_i \).

\[ D^*_i = \sqrt{\sum_{j=1}^n (v_{ij} - v^+_j)^2} \ i = (1, 2, \ldots, m) \]

\[ D^-_i = \sqrt{\sum_{j=1}^n (v_{ij} - v^-_j)^2} \ i = (1, 2, \ldots, m) \]  

(4)

- Calculate the proximity of the alternatives to positive and negative ideal solutions

\[ \varepsilon_i = \frac{D^-_i}{D^*_i + D^-_i} \]  

(5)

4. An empirical analysis of green material supplier selection model

Assuming that a company needs to select one material supplier from five competitors named A, B, C, D, and E. According to the evaluation index system and the actual situation of those material suppliers, Table 1, each supplier's index evaluation value can be seen in Table 1.

| Level 1 | Level 2 | A       | B       | C       | D       | E       |
|---------|---------|---------|---------|---------|---------|---------|
| A1      | A11     | 85%     | 83%     | 89%     | 91%     | 86%     |
|         | A12     | 7       | 8       | 6       | 7       | 8       |
|         | A13     | 11%     | 13%     | 9%      | 8%      | 10%     |
|         | A14     | 94%     | 92%     | 93%     | 94%     | 95%     |
| A2      | A21     | 3       | 5       | 4       | 3       | 2       |
|         | A22     | 8       | 8       | 8       | 8       | 8       |
|         | A23     | 7       | 8       | 6       | 7       | 7       |
|         | A24     | 2%      | 1.40%   | 1.70%   | 1%      | 1.60%   |
| A3      | A31     | 0.80%   | 0.50%   | 0.70%   | 0.60%   | 0.50%   |
|         | A32     | 5       | 6       | 5       | 7       | 5       |
|         | A33     | 6       | 7       | 4       | 7       | 6       |
|         | A34     | 28%     | 25%     | 20%     | 24%     | 29%     |
|         | A35     | 85%     | 89%     | 87%     | 80%     | 82%     |
|         | A36     | 35%     | 40%     | 42%     | 38%     | 39%     |
4.1. Calculate the weight of the indicators
According to the calculation steps of the entropy method listed in this paper, the data processing is performed by EXCEL software, and the results as follows: \( n = 14, \ln 14 = 2.6391, K = \frac{1}{\ln 14} = 0.3789 \)

4.2. Calculate the distance between the indicator values of each green material supplier to the ideal solutions and negative ideal solutions.
1) According to the above calculation formula (1) to formula (5), the results as follows:
\[
D_1^+ = 0.0114, D_1^- = 0.0149, D_2^+ = 0.0097, \\
D_2^- = 0.0183, D_3^+ = 0.0141, D_3^- = 0.0122, \\
D_4^+ = 0.0158, D_4^- = 0.0109, D_5^+ = 0.0170, \\
D_5^- = 0.0105
\]

2) Calculate the proximity of the alternatives to positive and negative ideal solutions and select suitable supplier
\[
\varepsilon_i = \frac{D_i^+}{D_i^+ + D_i^-} = \frac{0.0149}{0.0114 + 0.0149} = 0.5665
\]

By the same way, we can get \( \varepsilon_2 = 0.6527, \varepsilon_3 = 0.463, \varepsilon_4 = 0.4082, \varepsilon_5 = 0.3818 \)

5. Conclusion
According the results, we easily know \( \varepsilon_2 > \varepsilon_1 > \varepsilon_3 > \varepsilon_4 > \varepsilon_5 \), so supplier B is the first candidate.

In this paper, we combine the Entropy weight method and TOPSIS to establish the green material supplier selection model, whose evaluation results can provide an objective and comprehensive evaluation of the suppliers, and can help purchasers effectively choose the suitable green material suppliers as their long-term strategic partners. The joint efforts of the purchasers and excellent green material suppliers are of great significance to the sustainable development of the construction industry. However, the shortcomings of this paper lie in the construction of supplier evaluation index system, and the future research can be done to consider more and enrich the evaluation index system.

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