Supplier Selection and Evaluation System of Delphi Method and Analytic Hierarchy Process

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Abstract. In order to solve the problem of selecting and evaluating suppliers by subjective experience and emotional factors. In combination with the actual situation of the enterprise and the plan for the next ten years, an expert group was set up according to multi-attribute, group decision, the basic principles and steps of supplier selection and evaluation, and 4 first-level indicators of quality, cost, delivery time and service and 11 second-level indicators corresponding to each first-level indicator were selected by Delphi method. Analytic hierarchy process was used to determine the weight of each index, and a suitable supplier selection and evaluation system was constructed. This paper improved the current situation of supplier selection and evaluation, which was beneficial to the long-term development of enterprises.

1. Introduction

With the development of the global market, the competition between enterprises is increasingly fierce. At the same time, due to the progress of scientific and technological level and the increasing personalized demands of consumers, products are being replaced more and more rapidly, and enterprises are facing great challenges [1]. Therefore, enterprises can only cope with the complex environment and improve their profits by establishing a good cooperative relationship with other enterprises in the supply chain. As an important component of supply chain, suppliers play an important role. Only when enterprises choose suppliers that are suitable for their actual situation and meet their future development needs, which can they promote their progress and development and enhance their competitiveness [2]. Enterprise competitiveness is characterized by high quality products and low production costs relative to competitors. The quality and price of materials supplied by suppliers greatly affect the final quality and price of products [3].

In the process of practice, it is found that the selection and evaluation of suppliers in enterprises are usually led by the procurement department and assisted by the technical department. However, in the actual process, the technical department does little or nothing in the selection and evaluation of suppliers, and the selection and evaluation of suppliers are entirely undertaken by the procurement department. Procurement department personnel mostly rely on their own subjective experience and emotional factors to select suppliers, lack of a correct and scientific supplier selection and evaluation criteria. Especially with the decline of product profits in the current market, it is an indispensable process for enterprises to choose the right and appropriate suppliers and establish a good cooperative relationship to reduce costs and improve product quality. Therefore, effective supplier selection and evaluation is of great significance to enterprises and public institutions, and has always been the key research subject of enterprises and public institutions [4-5].
2. Supplier selection and evaluation status

The company is a manufacturing enterprise engaged in the development and manufacturing of advanced carbon fiber composite materials. At present, the company's suppliers are mainly divided into: chemical industry, raw materials, hardware, packaging, printing, processing, mold and other categories, a total of 284 qualified suppliers. According to the quality control data of the company's incoming materials, it is known that the incoming materials affect the quality of the products by 50%. The final products produced by the company are closely related to the quality of the incoming materials. Therefore, it is necessary to establish the supplier evaluation indicators for the company to evaluate and select suppliers with good faith and reliable quality.

2.1. Selection and evaluation process

Supplier selection and evaluation mainly had the division of labor between purchase department, quality department and technology department. The work process and the responsibility department was shown in Table 1.

| Process                                    | Rights and liabilities            |
|--------------------------------------------|----------------------------------|
| Supplier demand                            | Demand department                |
| Supplier search                            | Purchase department              |
| Supplier demand                            | Purchase, Technology, Quality department |
| Establish qualified supplier database       | Purchase department              |
| Supplier evaluation                        | Purchase, Quality department     |
| Maintain evaluation records                | Purchase department              |

2.1.1. Assessment method. The company supplier evaluation indicators included quality, delivery period, quality certification, respectively by the product insurance, procurement, product protection department appraisal, and according to the final assessment score to be divided into good, medium and poor grade.

2.2. Selection and evaluation analysis

As the customer has improved the quality requirements of the product year by year, the supplier selection and evaluation system has not been adjusted. Through the research and analysis, the following questions were found:

(1) The supplier evaluation index was not perfect. For example, the evaluation index of the supplier index is made up of quality, delivery and quality certification. That cannot reflect the actual situation of the supplier. It was found that some suppliers reduced the cost of the product by reducing the quality of the product. So the corresponding evaluation indexes are added in the supplier selection and evaluation system.

(2) Supplier management was extensive. The company was not systematically classified by suppliers and candidate suppliers, and they will be inspected by the candidate suppliers, resulting in the waste of human, material and financial resources.

(3) The division of responsibility was vague. There was a lack of execution in the implementation process, and the ambiguity of the responsibility of the department was unclear.
3. Supplier selection and evaluation optimization scheme

3.1. Supplier classification and process optimization

In order to facilitate the management of suppliers and avoid the non-necessary factory inspection of general suppliers, reduce the waste of human, material and financial resources. The supplier of the company was classified: key supplier, more important supplier, general supplier. According to the analysis, the supplier selection and evaluation process of the company was optimized, as shown in Figure 1.

![Optimized supplier selection and evaluation flow chart](image)

**Figure 1. Optimized supplier selection and evaluation flow chart**

3.2. Evaluation index

This paper used Delphi method to select and evaluate the supplier selection. Delphi method is a method which includes expert knowledge and group decision making [6-7]. The steps were as follows:

1. Draw up the outline of the investigation. Prepared the current evaluation indexes, the work process and other background materials, explaining the goal of selecting the supplier selection and evaluation index for the actual situation of the company.

2. Constitute the panel of experts. The composition of the experts: purchase group leader, purchase leader, IQC leader, research leader and laboratory leader. Because they have deep experience and rich theory in supplier selection and evaluation. The secretary of the expert group was set up to integrate the information and the experts’ opinions.
(3) Consult. The panel members proposed supplier selection and evaluation indicators, and the secretary of the expert group collected and analysed the expert opinions. In the first round, all the expert opinions were summarized, as an optional indicator for anonymous situations. Candidate index selection principle: if all experts agreed that the index was a candidate index, all experts would be excluded from the index, and the experts would remain the indicator, until the index of supplier selection and evaluation were selected. In normal circumstances, there is no more than four rounds of consultation. This paper conducted four rounds of consultation.

(4) Confirm the index. In the fourth round, the indexes of the pre-convergence were once again issued to the experts, and the index of supplier selection and evaluation was selected. The company supplier selection and evaluation index system was shown in Figure 2.

3.3. The weight of the evaluation index

Based on the supplier selection and evaluation index, this paper used Analytic Hierarchy Process [8] to calculate the weight of the index.

3.3.1. Criterion layer index weight. The judgment matrix was built by comparing the two elements. The index weight and the maximum characteristic value were calculated. In order to calculate the accuracy of the results, this paper used the yaaph software to test the results.

(1) Build the judgment matrix. The judgment matrix of four indicators was shown in Table 2.

(2) Calculate the single order right vector. From the formula \(W_i = (\Pi_{j=1}^{n}a_{ij})^{1/n}\).

\[
\begin{align*}
W_1 &= (1 \times 3 \times 3 \times 5)^{1/4} = 2.590 \\
W_2 &= (\frac{1}{3} \times 1 \times \frac{1}{3} \times 3)^{1/4} = 0.76 \\
W_3 &= (\frac{1}{3} \times 3 \times 1 \times 7)^{1/4} = 1.627 \\
W_4 &= (\frac{1}{5} \times \frac{1}{3} \times \frac{1}{7} \times 1)^{1/4} = 0.312
\end{align*}
\]

\[\sum_i W_i = W_1 + W_2 + W_3 + W_4 = 5.289\]

Therefore, the weight of Quality, Cost, Delivery and Service index was 0.49, 0.143, 0.308, 0.059.
(3) Calculate the maximum characteristic root. From the formula \( \lambda_{\text{max}} = \sum_{i=1}^{n} (AW)_{ii} / nW_i \) and \((AW) = [a_{ij}] [W]^T\), the maximum eigenvalue of the judgment matrix \( \lambda_{\text{max}} = 4.235 \).

(4) Consistency test. The consistency index \( CI = 0.078 \) and \( CR = 0.087 \) met the consistency requirement.

| criterion layer | Quality | Cost | Delivery | Service |
|-----------------|---------|------|----------|---------|
| Quality         | 1       | 3    | 3        | 5       |
| Cost            | 1/3     | 1    | 1/3      | 3       |
| Delivery        | 1/3     | 3    | 1        | 7       |
| Service         | 1/5     | 1/3  | 1/7      | 1       |

Table 2. Index judgment matrix in criterion layer

3.3.2. Factor layer index weight. According to the same method, the evaluation weights of the evaluation index were calculated, as shown in Table 3.

| Criterion layer | Elements layer | The total weight of elements layer |
|-----------------|----------------|----------------------------------|
| Index           | Weight         | Index                            | Weight |
| Quality         | 0.49           | Present of pass                   | 0.092  | 0.045  |
|                 |                | Quality restriction               | 0.409  | 0.2    |
|                 |                | Quality compliance rate           | 0.36   | 0.176  |
|                 |                | Quality process control           | 0.139  | 0.068  |
| Cost            | 0.143          | Price competition                 | 0.75   | 0.108  |
|                 |                | Depreciate                        | 0.25   | 0.036  |
| Delivery        | 0.308          | Delivery accuracy                 | 0.5    | 0.154  |
|                 |                | Delivery rate                     | 0.5    | 0.154  |
| Service         | 0.059          | Communication                     | 0.455  | 0.027  |
|                 |                | Product design                    | 0.09   | 0.005  |
|                 |                | Fault diagnosis                   | 0.455  | 0.027  |

Through the above analysis, it could be seen that the index of elements layer contain both quantitative information and qualitative information. In order to make the grading scientific, the grading standard of the element layer was formulated [9].

1) The full score of a single index was 10.

2) Qualitative and quantitative indicators were divided into four grades, with scores ranging from 9-10, 8-9, 6-8 and 0-6. Quantitative indicators include 5 indicators, such as present of pass, quality compliance rate, price competition, depreciate, delivery rate. The score is evaluated according to the calculated results of quantitative indicators \( \geq 90\% \), 80\%-90\%, 60\%-80\% and < 60\%. The remaining qualitative indicators were judged as excellent, good, medium and poor.

3.4. Responsibilities of supplier selection and evaluation department

In order to avoid the fact that only the procurement department was responsible for supplier selection and evaluation, the responsibilities of each department were divided as follows:
(1) Purchase department: be responsible for suppliers selection and evaluation, supplier service tracking and evaluation, and supplier information.
(2) Quality department: participate in supplier evaluation and selection, supplier service tracking and evaluation.
(3) Technical department: participate in supplier evaluation and selection and sample test.

4. Conclusion
Based on the study and summary of relevant theories of domestic and foreign suppliers, this paper analyzed the current situation of supplier selection and evaluation of the company, and optimized the supplier selection and evaluation process of the company. The supplier evaluation index of the company was solved by Delphi method. Establish a supplier evaluation index system more suitable for the company from four aspects of quality, cost, delivery time and service. Use analytic hierarchy process to solve the weight of 11 indexes in the factor layer, and give the evaluation method of the index in the factor layer. The responsibility of each department in supplier selection and evaluation was clarified, and the specific division of labor for evaluation team to participate in evaluation was given. However, there were some deficiencies in this paper. For example, the current global cooperation and competition were becoming more and more prominent. Whether the supplier selection and evaluation system should consider the factors of competitors needed to be further improved in the later research.

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