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RESEARCH ON SUPPLIER SELECTION STRATEGY BASED ON AHP

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Abstract: As an important resource for enterprise production, the selection of suppliers is crucial. This paper takes Company Q as the research object, determines the supplier evaluation indexes of this company through expert scoring method and field research, and uses hierarchical analysis method to quantitatively analyse the supplier's indexes and determine the weight coefficients. From the four dimensions of having quality level, product price, delivery ability, service level and comprehensive ability, four suppliers are selected for evaluation, and the optimal supplier is selected based on the evaluation results.
Keywords: Supplier selection; Supplier management; Hierarchical analysis; Python

1 INTRODUCTION

With the increasingly fierce competition in the global market, manufacturers are increasingly aware of the importance of establishing close collaborative relationships with their suppliers. Especially in the framework of optimising resource allocation and enhancing economic efficiency, a superior supplier plays a pivotal role [1]. Through effective supplier management, these suppliers can continue to provide enterprises with stable and high-quality raw materials and components, thus achieving effective cost control. Such cost savings not only help to improve the operational efficiency of enterprises, but also significantly enhance their market competitiveness. Therefore, how to select the most suitable suppliers for the needs of enterprises has become one of the key factors for manufacturers to achieve competitive advantage.

Supplier selection is the core of supplier management. In domestic and international research, the focus is mainly on constructing evaluation indexes and selection methods for supplier selection, and fruitful results have been achieved in the research on the index system of supplier selection.Dickson GW [2], systematically identifies and refines 23 key indexes for assessing supplier capability, as shown in Table 1.

Table 1 Vendor Selection Factors

Ordinal number	Factors	evaluations	Ordinal number	Factors	evaluations
1	Quality	RI	13	Management & Organisation	AI
2	Delivery	CI	14	Operational Control	AI
3	Historical benefits	CI	15	Maintenance Service	AI
4	Guarantee	CI	16	Attitude	AI
5	Production facilities	CI	17	Image	AI
6	Price	CI	18	Packaging Capability	AI
7	Technical capacity	CI	19	Labour relations record	AI
8	Financial status	CI	20	Geographic location	AI
9	Follow the quotation process	AI	21	Past business volume	AI
10	Communication system	AI	22	Personnel training support	AI
11	Reputation	AI	23	Business Reciprocity	SI
12	Business expectations	AI			

Note:EI is Extreme Importance;CI is Considerable Importance;AI is Average Importance;SI is slight Importance.

Since then, many researchers have rearranged and explored the priorities based on the criteria proposed by Dickson, further expanding and deepening the research scope of supplier management indicators and revealing more considerations that are crucial in the process of supplier selection and evaluation. Through extensive collection of literature, this study has sorted out the elements of supplier selection evaluation indexes that have attracted much attention at home and abroad, as shown in Table 2.

Table 2 Indicator Elements for Supplier Selection

Authors	Indicator elements
Caddick[3]	Performance in previous years, quality level, production plan management system, purchase price
Marina Segura[4]	Research investment, product innovation capability, product development capability
HenkAkkermans[5]	Quality, delivery, technology, service, innovation ability, depth of co-operation
Tavana A B[6]	Corporate governance, management, staff team, production lines
Kumar[7]	Cost, delivery, location, quality, communication, management, performance, reputation
Singh[8]	Economy, product strength, organisation, green/environmental initiatives, supply risks, technology, social culture
Wang Xu Ping and Chen Ao[9]	Technology development, information technology level, business capability and after-sales service
Xu Qin and Yu Ge[10]	Enterprise creditworthiness, research capability, quality management capability, co-operation capability
Chen Jinglin[11]	Enterprise background and qualification, manufacturing capability, quality management, business management, customer service
Wu Yiwen[12]	Cost, quality, delivery, financial status, management level, service level, external environment
Yu Chunxia[13]	Price, quality, service level, environmental protection ability, supplier reputation

Analysic Hierarchy Process (AHP), a systematic method for multi-criteria decision-making problems, was proposed by Thomas L. Saaty, an American operations researcher, in the 1970s [14]. The core idea of the method lies in constructing a hierarchical model by decomposing a complex decision-making problem into several levels. Typically, the topmost layer represents the overall goal of the decision, the middle layer covers the guidelines or criteria affecting the decision, and the bottom layer is the options or measures that can be chosen. The elements of each layer are sequentially compared and weighted relative to the previous layer, resulting in a model that reflects the decision maker's preferences. In this model, the decision maker makes subjective judgements about the importance of each factor and expresses these preferences through a series of pairwise comparisons. Such pairwise comparisons are quantified in a mathematical form and used to calculate the relative weights or importance of the factors. This clear and structured approach to the multi-criteria decision-making problem enables qualitative judgements to be transformed into quantitative analyses, providing a framework for rational analysis by the decision maker.

This paper takes Company Q as the research object, and through analysing the company's suppliers, it is found that the company has the following supplier selection problems, firstly, the organisational structure of supplier selection is unreasonable; secondly, the existing evaluation indexes of supplier selection are single and confusing; and thirdly, the supplier selection process is not standardised. Therefore, this paper constructs a supplier evaluation model based on the hierarchical analysis method, hierarchises the complex problems, and proposes supplier selection and management strategies based on the evaluation results.

2 SUPPLIER SELECTION EVALUATION SYSTEM BASED ON AHP

2.1 Selection of the Components of the Indicator System

The supplier evaluation index system is an important basis used for comprehensive assessment and selection of suppliers [15]. Firstly, the main indicators affecting supplier selection are sorted out based on past literature analysis and actual research. Secondly, a supplier evaluation model containing the target layer, criterion layer and programme layer was constructed based on AHP. Among them, the criterion layer is subdivided into two layers, and the first-level indicators include quality level, product price, delivery capability, service level and comprehensive capability; the second-level indicators of the criterion layer involve 16 factors such as product qualification rate, and the specific indicators are shown in Figure 1.

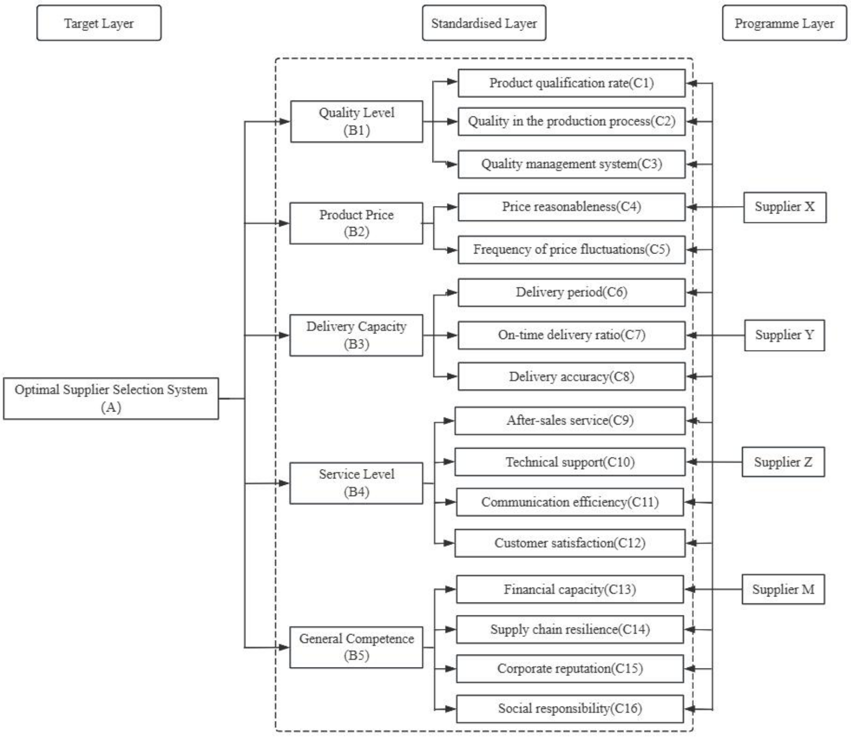

Figure 1 Supplier Evaluation System

(1) Quality level

In the supplier evaluation index system, quality level as a first-level indicator is usually used to assess the supplier's performance in product quality and production management. It consists of 3 parts, namely, product pass rate, quality management level and production process quality, and measures the supplier's quality control ability and reliability from different perspectives. Product pass rate refers to the proportion of products produced by the supplier that comply with quality standards and technical specifications. This indicator reflects the supplier's ability and stability to meet quality standards in the manufacturing process. A high product pass rate indicates that the supplier's production process, raw material control and quality inspection procedures are more stringent and effective, and that it is able to consistently provide high-quality products that meet customer requirements. Quality management system refers to a set of systematic management processes and control measures established by the supplier to ensure the quality of its products and services. Production process quality refers to the supplier in the actual production process, to ensure that the product meets the quality requirements of the specific control measures and quality assurance activities.

(2) Product price

Product price includes two secondary indicators, price reasonableness and price fluctuation frequency, from the rationality and stability of the two aspects of the supplier's pricing strategy and market adaptability. Price reasonableness refers to the competitiveness of the product price offered by the supplier within the market, and whether its pricing matches the product quality and service level. The frequency of price fluctuations reflects the stability and market responsiveness of the supplier's product price adjustment. The frequency and magnitude of price adjustments are assessed by analysing the supplier's record of price changes, the reasons for such changes and contractual terms and conditions. Lower frequency of price fluctuations usually indicates the stability of the supplier's pricing strategy, which helps enterprises to maintain the predictability and stability of procurement costs.

(3) Deliverability

Deliverability consists of three components: delivery period, on-time delivery rate and delivery accuracy. Delivery period refers to the supplier from the order to complete the delivery of the time required, a direct reflection of its production efficiency and logistics response speed, is an important factor in measuring its ability to perform. On-time delivery rate measures the supplier's ability to deliver products as planned within the specified time, reflecting its effective control of production planning and supply chain management, as well as its resilience and robustness in dealing with uncertainties. Delivery accuracy, on the other hand, focuses on the extent to which the supplier's requirements for quantity, quality and specifications are met in the delivery process, reflecting its ability to follow the terms of the contract and its integrity in the execution of the order.

(4) Service Level

The four secondary indicators of after-sales service, technical support, communication efficiency and customer satisfaction provide a comprehensive assessment of the level of supplier service. After-sales service refers to the supplier's maintenance, repair and service response capability after product delivery, reflecting its timely handling of customer issues and continuous support, which directly affects the customer's long-term experience of using the product. Technical support evaluates the supplier's ability to provide customers with technical guidance, training and consulting, as well as its professionalism in solving complex technical problems, reflecting its ability to provide value-added services in technical cooperation. Communication Efficiency measures the speed and accuracy of the supplier's information transfer, problem feedback and decision-making response, representing its synergistic effect in business interactions. Customer satisfaction measures the overall evaluation of the supplier's service performance, reflecting the degree of customer recognition of the supplier's service quality.

(5) Comprehensive Capability

Supply chain resilience, financial capability, corporate reputation and social responsibility are selected as the secondary indicators of suppliers‘ comprehensive capability to comprehensively measure suppliers’ overall strength and sustainable development capability from different dimensions. Supply chain resilience assesses suppliers' resilience and ability to continue supplying goods in response to market fluctuations, supply disruptions and other uncertainties, and ensures the stability of production in a complex environment. Financial capability measures the supplier's financial health and risk resistance, reflecting the reliability of its long-term performance and stable operation. Corporate reputation represents a supplier's credibility and image in the marketplace, affecting its credibility and value of cooperation in quality management, contract fulfilment and customer service. Social responsibility focuses on suppliers' performance in environmental protection, employee rights and social contribution, and ensures that the supply chain is in line with the company's sustainable development strategy and social expectations.

2.2 AHP Supplier Evaluation Indicator Mode

2.2.1 Constructing judgement matrices for selecting indicators

The role of constructing judgement matrix in AHP is to determine the relative importance between each evaluation index at the same level, and to provide a basis for subsequent weight calculation and decision-making. In this paper, we use the expert scoring method to assign values to the importance of each indicator, and adopt the 9-scale method to make two-by-two comparisons to quantitatively analyse the target layer and criterion layer respectively.The judgement matrix for the total target layer A is shown in Table 3.

Table 3 Judgement Matrix of the Criterion Layer for the Target Layer

A	B_1	B_2	B_3	B_4	B_5
B_1	1	5	3	7	4
B_2	1/5	1	1/3	3	1/2
B_3	1/3	3	1	5	2
B_4	1/7	1/3	1/5	1	1/4
B_5	1/4	2	1/2	4	1

According to the same method as the construction of the target layer matrix, for the criterion layer B can be listed separately as the judgement matrix of the quality level, product price, delivery capability, service level, and comprehensive capability indicators, as shown in Table 4-8.

Table 4 Judgement Matrix of Quality Level Indicators

B_1	C_1	C_2	C_3
C_1	1	3	5
C_2	1/3	1	2
C_3	1/5	1/2	1

Table 5 Judgement Matrix of Product Price Indicators

B_2	C_4	C_5
C_4	1	5
C_5	1/5	1

Table 6 Judgement Matrix for Delivery Capacity Indicators

B_3	C_6	C_7	C_8
C_6	1	1/4	1/5
C_7	4	1	2
C_8	5	1/2	1

Table 7 Judgement Matrix for Level-of-Service Indicators

B_4	C_9	C_{10}	C_{11}	C_{12}
C_9	1	2	4	1/3
C_{10}	1/2	1	3	1/4
C_{11}	1/4	1/3	1	1/5
C_{12}	3	4	5	1

Table 8 Judgement Matrix for the Composite Capacity Indicator

B_5	C_{13}	C_{14}	C_{15}	C_{16}
C_{13}	1	3	5	7
C_{14}	1/3	1	3	5

C_{15}	1/5	1/3	1	3
C_{16}	1/7	1/5	1/3	1

2.2.2 Calculation of the weights of the indicators and consistency test

(1) Weight calculation

Each indicator in the hierarchical structure has a different proportion of the target [16], and the weights can be used to quantify the relative importance of each evaluation indicator, by transforming the subjective judgement of experts or decision makers into objective data. Using python software, the eigenvalue decomposition of the judgement matrix is performed to calculate the maximum eigenvalues and their corresponding eigenvectors, and the eigenvectors are normalised to obtain the relative weights of each evaluation index.

The weight vectors of each matrix calculated by Python are as follows:

Vector of weights for the overall objective A:$W_A = [0.484\ \ 0.095\ \ 0.229\ \ 0.045\ \ 0.147]^T$

Weight vector for quality level B_1:$W_{B_1} = [0.648\ \ 0.230\ 0.122]^T$

Weight vector for product price B_2:$W_{B_2} = [0.833\ \ 0.167]^T$

Weight vector for delivery capability B_3:$W_{B_3} = [0.102\ \ 0.532\ \ 0.366]^T$

Weight vector of service level B_4:$W_{B_4} = [0.244\ \ 0.153\ \ 0.072\ \ 0.531]^T$

Weight vector of overall capability B_5:$W_{B_5} = [0.558\ \ 0.263\ \ 0.122\ \ 0.057]^T$

(2) Consistency test

Based on the maximum eigenvalue, the consistency index (CI) and consistency ratio (CR) are calculated to verify the consistency of the judgement matrix. If the consistency ratio is full CR < 0.1, the consistency of the judgement matrix can be considered reasonable to ensure the scientificity of the weight allocation.Python specific calculation results are shown in Table9.

Table 9 Consistency Test Results

Matrix	λ_{Max}	CR	CI
A	5.138	0.035	0.031
B_1	3.004	0.001	0.003
B_2	2.000	0	0
B_3	3.095	0.047	0.082
B_4	4.119	0.040	0.044
B_5	4.118	0.039	0.044

According to the values shown in Table 9, the CR value of each matrix is less than 0.1, so it passes the consistency test, proving that the judgement matrix of the designed optimal supplier selection model is set more reasonably. Accordingly, the evaluation system of the supplier selection model is obtained, as shown in Table 10.

Table 10 Overall Hierarchical Ordering

Overall Target	Level 1 indicators	Level 1 indicator weights	Level 2 indicators	Level 2 indicator weights	Portfolio weights	Arrange in order
Optimal Supplier Selection System (A)	Quality Leve (B_1)	0.484	Product qualification rate	0.648	0.314	1
			Quality in the production process	0.230	0.111	7
			Quality management system	0.122	0.059	2
	Product Price (B_2)	0.095	Price reasonableness	0.833	0.079	8
			Frequency of price fluctuations	0.167	0.016	13
	Delivery Capacity (B_3)	0.229	Delivery period	0.102	0.023	4
			On-time delivery ratio	0.532	0.122	3
			Delivery accuracy	0.366	0.084	14
	Service Level (B_4)	0.045	After-sales service	0.244	0.011	12
			Technical support	0.153	0.007	6
			Communication efficiency	0.072	0.003	15
			Customer satisfaction	0.531	0.024	5
	General Competence (B5)	0.147	Financial capacity	0.558	0.082	9
			Supply chain resilience	0.263	0.039	16
			Corporate reputation	0.122	0.018	10
			Social responsibility	0.057	0.008	11

3 EXAMPLE ANALYSES

Take the procurement of spare parts of Company Q as an example, its alternative suppliers are X, Y, Z and M4 companies. Setting, each indicator is full of 100 points, with 0 being the lowest score, each indicator is scored by the evaluation group composed of company experts, and the evaluators can score the suppliers based on their actual performance and internal company information, and rank the scoring results. The assessment results should be specific, objective and fair, and can be explained and illustrated as necessary in the description of the assessment results[17]. The summary results of supplier scores are shown in Table 11.

Table 11 Summary Results of Supplier Scores

Level 1 indicators	Level 2 indicators	Portfolio weights	Supplier X Score	Supplier Y Score	Supplier Z Score	Supplier M Score
Quality Leve（B_1）	Product qualification rate	0.314	85	90	80	85
	Quality in the production process	0.111	80	85	75	80
	Quality management system	0.059	75	80	70	75
Product Price (B_2)	Price reasonableness	0.079	70	75	65	60
	Frequency of price fluctuations	0.016	65	70	60	80
Delivery Capacity (B_3)	Delivery period	0.023	80	85	75	70
	On-time delivery ratio	0.122	85	90	80	70
	Delivery accuracy	0.084	90	80	85	80
Service Level (B_4)	After-sales service	0.011	75	80	70	80
	Technical support	0.007	70	85	75	81
	Communication efficiency	0.003	80	80	65	75
	Customer satisfaction	0.024	85	90	75	75
General Competence (B5)	Financial capacity	0.082	70	85	75	77
	Supply chain resilience	0.039	75	80	70	80
	Corporate reputation	0.018	80	85	70	79
	Social responsibility	0.008	65	75	80	88
Totals			80.555	85.21	76.365	77.917
Sequence			2	1	4	3

According to the supplier evaluation system constructed in this paper and combined with the final score, it can be seen that: the score of Supplier X is 80.555, the score of Supplier Y is 85.21, the score of Supplier Z is 76.365, and the score of Supplier M is 77.917, so the optimal supplier for the procurement of spare parts in Company Q is Supplier Y, with which a strategic partnership can be formed to continually increase the trust in the cooperation Therefore, the optimal supplier for Company Q's spare parts procurement is Supplier Y, which can form a strategic partnership with it and continuously increase cooperation trust. At the same time, it should also maintain a good trading relationship with Supplier X and Supplier M in order to prevent the occurrence of supply chain risk problems caused by special circumstances.

4 CONCLUDE

This paper adopts the hierarchical analysis method to construct a supplier evaluation model, analyses the evaluation results of suppliers to help enterprises make supplier selection, and applies the model to Company Q as a real case to provide corresponding selection results and management strategies. It should be noted that each enterprise is in a different industry, and its specific situation has some differences, so the indicators in the model may not be applicable to all enterprises, and enterprises need to adjust the corresponding supplier evaluation indicators and strategies according to the actual situation.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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