Research on the Selection of Suppliers by Enterprises Based on the Entropy Weight Method

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Abstract. A reliable supplier can not only provide timely supplies during stock shortages but also ensure the quantity of goods supplied. Therefore, selecting reliable suppliers is of great significance for the operational management of a company. Based on existing research in supplier reliability evaluation, this article systematically constructs a comprehensive assessment index system. The system utilizes the entropy weight method, an objective empowerment model designed to avoid human subjective biases. Through six key indicators, this approach effectively assesses the supply risk and capability of suppliers. With this evaluation system, this study conducts a reliability assessment of 402 suppliers which utilizes the actual supply and order quantity data from a specific enterprise in the past 240 weeks. Through this process, a comprehensive score is calculated for each supplier, ultimately identifying the 50 most reliable partners. The research results of the paper have significant theoretical and practical implications for the evaluation and optimization of supplier reliability in the supply chain, which can provide insights for business managers.

Keywords: entropy weight method; supplier selection; inventory management; reliability assessment

1 Introduction

1.1 Background

With economic globalization, competition among modern enterprises has evolved into competition between suppliers, dominated by core enterprises, which causes the supply chain networks of enterprises to become increasingly complex. In such a complex system, suppliers, as the 'source' of the supply chain, directly determine the smoothness of subsequent production, logistics, and even customer delivery. A scientifically effective evaluation of the supply characteristics of suppliers enables enterprises to gain a comprehensive understanding of suppliers' actual performance, accurately identify high-quality partners, and subsequently reduce procurement risks while establishing long-term stable cooperative relationships [1]. To achieve this goal, enterprises rely on objective data to conduct multidimensional quantitative analyses of suppliers' supply

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capacity, stability, and historical transaction circumstances, thereby comprehensively evaluating their reliability. This scientific assessment system can accurately identify the most reliable group of suppliers for the subsequent stable operations of the enterprise.

1.2 Related Research

Currently, there is a considerable amount of research on the evaluation of supplier companies within the supply chain. Zhang Xiaodi and Wang Fenghua used Baosteel Co., Ltd. as their research subject to construct a performance evaluation index system for green supply chains [2]. They employed the entropy weight method to determine the weight of the indicators and propose strategies and suggestions based on the evaluation results. Jie Zeyu applied the Analytic Hierarchy Process (AHP) and the entropy weight method to obtain index weights and then extended the VIKOR method based on gray relational analysis to the context of Z-numbers, ultimately identifying the optimal supplier [3]. Hamed Taherdoost and Aurélie Brard reviewed some research about supply chain management, supplier selection criteria, and supplier selection evaluation methods (multi-criteria decision making) [4]. Göncü and Çetin develop a holistic Multi-Criteria Decision Making model as a decision support system for supplier selection in the health sector [5]. Konys proposed a systematic method for standard acquisition and integration through bibliometric analysis and ontology construction, which responds to the issue of knowledge dispersion in the selection criteria for green suppliers [6].

1.3 Motivation

The aforementioned studies have effectively researched supplier selection. However, the Analytical Hierarchy Process or expert scoring method largely relies on the experience and personal judgment of experts, resulting in a certain degree of subjectivity and uncertainty in the allocation of weights. The entropy weight method can maximize the exclusion of interference from human subjective factors, allowing the allocation of weights to be determined entirely by the inherent laws of the data itself and the amount of information provided. The entropy weight method posits that if an indicator exhibits greater variation among different suppliers, it signifies larger data fluctuations, which implies a stronger capability to differentiate and select suppliers, as well as an increased amount of information contained within it. Consequently, it is assigned a higher weight. This data-driven approach will make decision-making more scientific and persuasive.

The rest of this article is structured as follows. The research background and motivation and related papers summary are presented in Section1. Section2 is devoted to the description of data, indicators calculation formulas and research model prosess. Section3 represents the results of 50 the most reliable suppliers selected by entropy weight method using MATLAB. Section4 summarize the article.

2 Methodology

2.1 Source of Data

Based on existing research, this paper takes the first question of the c-topic from 2021 China Undergraduate Mathematical Contest in Modeling as a case study [7]. The data includes the order quantities and the actual supply quantities from enterprises over 240 weeks for 402 different suppliers. This paper conducts a quantitative analysis of the supply characteristics of 402 suppliers, establishing a mathematical model that reflects the importance of ensuring the production of enterprises. Based on this, it identifies the 50 most important suppliers.

2.2 Data Processing and Explanation of Symbols

Based on the existing data of order quantities and actual supply quantities between enterprises and 402 suppliers over 240 weeks, it is possible to calculate the order frequency and total order quantity for each supplier, as well as the actual supply frequency and supply quantities of the suppliers.

The symbols corresponding to the six indicators selected in this article are shown in Table 1.

Table 1. Symbol Definitions

Symbols	Description of Symbols
O_{ij}	The order quantity from the enterprise to supplier *j* in week *i*.
S_{ij}	The actual supply quantity of the supplier *j* in week *i*.
ON_j	The number of orders placed by the enterprise with the supplier *j* within 240 weeks.
SN_j	The actual number of deliveries by supplier *j* within 240 weeks.
SSN_j	The number of occurrences in which the actual supply quantity from the supplier *j* within 240 weeks equals the enterprise's order quantity.

$i, j \in Z,\ 0 < i \le 240,\ 0 < j \le 402$

Define Supply and Demand Ratio here. It is a quantifiable metric for measuring the degree of stockouts or the level of demand fulfillment, reflecting the completion of product delivery through the percentage of actual supply compared to corporate demand.

$$SDR_j = \frac{\sum_{i=1}^{240} S_{ij}}{\sum_{i=1}^{240} O_{ij}} \tag{1}$$

Considering the issue of supply risk, if the supplier's supply is much lower than the company's order quantity, it can lead to the company being unable to operate normally

and generate sufficient profit; if the supplier's supply is much higher than the company's order quantity, it will put great pressure on the company's inventory. Therefore, 146 suppliers were excluded because their SDR >1.1 or SDR < 0.1. This article aims to select the 50 most reliable suppliers from the remaining 257.

2.3 Indicator Selection

Based on the provided data, considering the supplier's risk and capacity comprehensively, the following six indicators are selected to evaluate the supplier's performance. Fig. 1 is the classification of the indicators, where indicators 1-3 reflect supply risks, and indicators 4-6 reflect supply capacity.

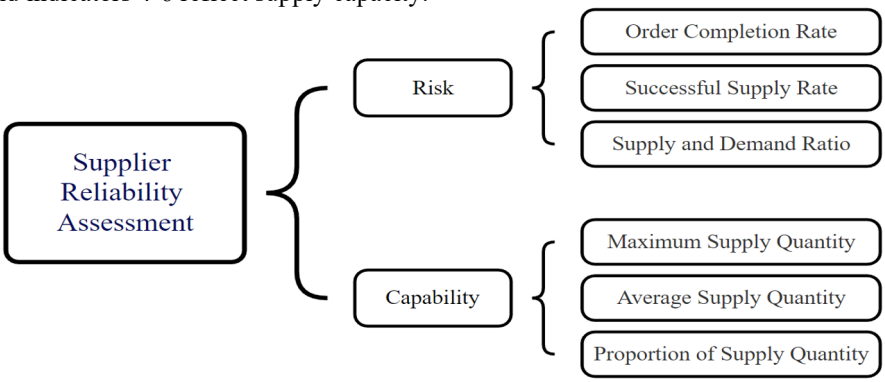

Fig. 1. Indicators Classification (Photo credit: Original)

(1)Order Completion Rate.

The order fulfillment rate refers to the ratio of the number of deliveries made by the supplier to the total number of orders placed by the enterprise. It not only reflects the integrity of the suppliers but also indirectly reflects the risk of stock shortages.

$$OCP_j = \frac{SN_j}{ON_j} \tag{2}$$

(2) Successful Supply Rate.

Successful supply is deemed to occur when the quantity supplied by the supplier exactly matches the order quantity. It refers to the supply quantity of the supplier being exactly equal to the ratio of the order quantity to the total number of supplies.

$$SSR_j = \frac{SSN_j}{SN_j} \tag{3}$$

(3) Supply and Demand Ratio.

It was defined in 2.2

(4) Maximum Supply Quantity.

The maximum quantity supplied by a certain supplier over a period of 240 weeks reflects that supplier's upper limit of supply capability.

(5) Average Supply Quantity.

It reflects the overall level of the supplier.

$$ASQ_j = \frac{1}{240}\sum_{i=1}^{240} S_{ij} \tag{4}$$

(6) Proportion of Supply Quantity.

Over the past 240 weeks, the supply quantities from 257 suppliers have varied, with the ratio of each supplier's supply quantity to the total supply quantity indicating their contribution proportion.

$$PSQ_j = \frac{\sum_{i=1}^{240} S_{ij}}{\sum_{i=1}^{240}\sum_{j=1}^{257} S_{ij}} \tag{5}$$

2.4 Models

The entropy weight method is an objective weighting method that calculates the entropy value of indicators based on the impact of changes in the values of each indicator on the overall situation, and then determines the weights. After processing the provided data, an evaluation index system was constructed systematically for supplier capability, which quantifies the supply characteristics of suppliers by using proper supply indicators. Subsequently, this paper utilizes the entropy weight method to objectively evaluate these indicators and calculates the weight of each indicator using MATLAB to evaluate the supplier reliability. The steps for calculating weights using the entropy weight method are as follows [8, 9].

(1)Construct the original matrix

There are a total of 257 evaluation subjects and 6 evaluation indicators. The original matrix X_{mn} is as follows.

$$X_{mn} = \begin{pmatrix} X_{11} & \cdots & X_{16} \\ \vdots & \ddots & \vdots \\ X_{257,1} & \cdots & X_{257,6} \end{pmatrix} \tag{6}$$

(2)Data Standardization

To eliminate the dimensional influence of different data, the original data is subjected to standardization processing. The formula is as follows. Adding 0.01 in the formula is to avoid having a zero in the standardization matrix Y_{mn}.

$$Y_{mn} = \frac{X_{mn} - \min(X_n)}{\max(X_n) - \min(X_n)} + 0.01 \tag{7}$$

$$m,n \in Z,\ 0 < m \le 257,\ 0 < n \le 6$$

(3)Calculate the degree of variation of indicators
Calculate the ratios P_{ij} of each indicator under each evaluation object.

$$P_{mn} = \frac{Y_{mn}}{\sum_{m=1}^{257} Y_{mn}} \tag{8}$$

(4)Calculate the entropy value en of each indicator
e_n represents the amount of information contained in that indicator.

$$e_n = -\frac{1}{\log 257} * \sum_{m=1}^{257} P_{mn} * \log(P_{mn}) \tag{9}$$

(5)Calculate the coefficient of variation d_n and the weights w_n.

$$d_n = 1 - e_n \tag{10}$$

$$w_n = \frac{d_n}{\sum_{n=1}^{6} d_n} (n = 1,2...,6) \tag{11}$$

(6)Use weights to assign to the original data, and calculate the final score to represent supplier reliability

$$\text{score}_m = \sum_{n=1}^{6} w_n * X_{mn} \tag{12}$$

Result Analysis and Discussion

2.5 Result Analysis

According to the entropy weight method calculation formula, the weights of the supplier evaluation indicators can be calculated by MATLAB, as shown in Table 2.

Table 2. The weights of the six indicators

Indicator	OCP	SSR	SDR	MSQ	ASQ	PSQ
weight	0.1484	0.1492	0.1533	0.1895	0.1718	0.1877

Finally, the original data is weighted to calculate a comprehensive score, from which the 50 most reliable suppliers are selected, as shown in Table 3.

Table 3. Rating List of the 50 Most Reliable Suppliers

1	S348	11	S308	21	S340	31	S352	41	S040
2	S201	12	S395	22	S275	32	S194	42	S365
3	S374	13	S037	23	S329	33	S114	43	S078
4	S140	14	S229	24	S131	34	S364	44	S003
5	S151	15	S361	25	S306	35	S291	45	S154
6	S126	16	S143	26	S086	36	S367	46	S031
7	S139	17	S282	27	S055	37	S208	47	S292
8	S330	18	S356	28	S268	38	S150	48	S080
9	S307	19	S338	29	S210	39	S273	49	S173
10	S108	20	S284	30	S074	40	S247	50	S346

2.6 Discussion

Reliable suppliers can significantly reduce the capital occupation and warehouse pressure caused by excessive inventory, or the huge losses caused by production stoppages due to material shortages. This study further proposes the following suggestions to promote the optimization of enterprise supplier management [10].

1. Implement precise classification driven by data and execute differentiated management strategies. Enterprises should classify all suppliers based on their reliability by comprehensive evaluation scores. Long-term strategic partnerships should be established with the most reliable suppliers, while an elimination process should be initiated for less reliable ones to optimize the supplier groups.

2. Coordinate supply and demand forecasts to optimize inventory management for constructing supply chain resilience. Share the Sales forecast and production plans moderately with suppliers to enable them to prepare materials and arrange production in advance, shortening delivery cycles and improving response speed.

3. Establish a dynamic scoring mechanism to regularly eliminate suppliers that impact operations. Data should be automatically collected every six months to update each supplier's comprehensive score and ranking. Suppliers with continuously declining scores will be required to make corrections; for suppliers that remain at the bottom for a prolonged period, the elimination process will be initiated.

3 Conclusion

In supply chain management, the selection and management of suppliers occupy a central position, significantly influencing the operations of enterprises and their competitive standing in the market. This paper first conducted a quantitative analysis of suppliers' capabilities and the risks associated with collaborating with them by selecting 6 indicators, which are based on data from the past 240 weeks of a company, specifically through order and supply data. Then use the entropy weight method to determine the weights of various indicators, as it can assess the overall impact based on changes in the values of each indicator and calculate the entropy value of the indicators. Finally, assign the weights of each indicator to the original data and calculate the

comprehensive score for each supplier to select the 50 most reliable suppliers. This study focuses on how to apply the entropy weight method for objective weighting, overcoming subjective biases, thereby achieving data-driven scientific decision-making, and subsequently proposing management optimization recommendations based on this. Although this method can get weights from objective data, it cannot reflect the interrelation among indicators, such as relevance and hierarchical relationships. Different levels of indicators need to be analyzed separately to prevent excessive bias towards a particular aspect. For further research, it is also necessary to incorporate business experience in the selection of indicators.

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