Comprehensive Evaluation of the Operation Status of Highway Lighting Equipment Suppliers

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Abstract. With the continuous development of the transportation industry, the demand for equipment by highway enterprises is also increasing day by day. Therefore, various highway enterprises will purchase a large amount of highway equipment to meet market requirements, and the selection of suppliers plays a decisive role. Choosing a suitable supplier is a guarantee of the integrity of the enterprise's supply chain. This paper adopts a scientific comprehensive evaluation method to evaluate the suppliers of highway lighting equipment. The suppliers are evaluated from both vertical and horizontal aspects through comprehensive index analysis and the queuing method based on estimated relative positions, providing reference for highway enterprises to choose suppliers.

Keywords: Highway, suppliers, comprehensive evaluation, lighting equipment

1 INTRODUCTION

The global economic development is driving the gradual upgrading of competition in the transportation industry, and the supply chain is the lifeline of enterprises [1]. Therefore, enterprises should choose suppliers more scientifically. The comprehensive evaluation method refers to the use of systematic and standardized methods to evaluate multiple indicators and units simultaneously. It is not just a method, but a method system, referring to a series of effective methods for synthesizing multiple indicators, which have a wide range of applications in the industry. Comprehensive evaluation is the establishment of an evaluation index system for the research object, using certain methods or models to analyze the collected data and make quantitative overall judgments on the evaluated things. It is widely used in the highway industry, including the evaluation of highway maintenance [2], the evaluation of highway pavement quality [3], and the comprehensive evaluation of highway service area facilities [4]. Using the comprehensive evaluation method to evaluate the operating conditions of suppliers can provide constructive reference for enterprises to select suppliers to a certain extent.

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Currently, there is a keen interest in conducting qualitative and quantitative analysis of financial performance indicators for listed companies. Financial indicators play an important role in the production and operation process of enterprises. The use of various basic financial performance indicators and financial analysis methods to study corporate financial data has significant implications for evaluating the current state of the enterprise and predicting its future [5]. This paper selects three highway lighting equipment suppliers, analyzes their annual reports for 2022, selects multiple indicators, and analyzes and ranks the business performance of the three enterprises through two commonly used comprehensive evaluation methods: the comprehensive index method and the queuing method based on estimated relative positions. By comprehensively using different evaluation methods, the business operation of enterprises can be more scientifically, objectively, and reasonably evaluated [7]. This comprehensive evaluation method can help decision-makers more comprehensively understand and evaluate the risks of highway supplier development, and make corresponding decisions and choices [8].

2 EVALUATION METHODS

2.1 Comprehensive index method

We select the comprehensive index method to conduct a longitudinal evaluation of the business status of three highway lighting equipment suppliers. The comprehensive index method refers to a method of calculating the comprehensive value of economic benefits by weighting the individual indices of various economic benefits based on the determination of a reasonable system of economic benefits indicators, in order to comprehensively evaluate economic benefits. That is to say, a group of same or different index values are standardized by statistical processing to standardize the index values of different Unit of measurement and properties, and finally converted into a comprehensive index to accurately evaluate the comprehensive level of work. The larger the comprehensive index value, the better the quality of work, and there is no limit to the number of indicators. The comprehensive index method converts various economic benefit indicators into individual indices of the same measurement, which facilitates the integration of various economic benefit indicators. The comprehensive economic benefit index is used as the basis for the ranking of comprehensive economic benefits among enterprises. The weights of various indicators are determined based on their importance, reflecting the magnitude of their role in the comprehensive value of economic benefits.

The basic idea of the comprehensive index method is to combine the weight factors of each indicator with their corresponding scoring values to obtain a weighted comprehensive score, thereby obtaining comprehensive evaluation results for different entities or schemes [6].

2.2 Scheme queuing method based on estimating relative position

This paper selects a queuing method based on estimating relative positions to conduct a relative evaluation of the business performance of three highway lighting equipment suppliers. Due to the fact that most evaluation methods require a large amount of initial information, a decision matrix needs to be provided in advance, which means the numerical values of each attribute of each evaluation object need to be given. However, in many cases, some attributes cannot or are difficult to quantify, and a decision matrix cannot be provided. Decision makers can only provide the order of advantages and disadvantages of each candidate partner under each attribute. The queuing method based on estimating relative position is a good method for solving such problems. Therefore, this paper uses the queuing method based on estimating relative position to evaluate the operational status of enterprises.

3 INDEX SYSTEM CONSTRUCTION AND WEIGHT DETERMINATION

Indicator weight refers to the contribution of a single indicator to the overall goal, and is an important coefficient that reflects the status of each indicator in the evaluation system. At present, the common methods to determine the index weight include Delphi method (expert scoring method), entropy method, factor analysis method, analytic hierarchy process (AHP), etc. Since there are many evaluation indicators in this study, and most of them are close to the actual management situation, the weight assignment needs to be conducted under the guidance of experienced experts, so this paper selects the Delphi method (expert scoring method) to determine the weight of each indicator. Based on experience and referring to relevant domestic and foreign research, analyze and propose preliminary opinions on indicator weights, and solicit opinions from relevant experts to ultimately determine indicator weights, forming an evaluation indicator system, as shown in Table 1.

Table 1. Evaluation index system

Index	Index Properties	Indicator unit	weight
Operating Revenue	forward direction	billion	0.2
Deposit Received	forward direction	billion	0.2
Per Capita Profit Earnings and Tax Payment	forward direction	yuan/person	0.1
Property	forward direction	billion	0.1
RAROC	forward direction	%	0.2
Social Contribution Rate	forward direction	%	0.2

4 Comprehensive Evaluation Method for Operating Status of Equipment Suppliers

4.1 Data collection

Based on relevant literature, six specific indicators were selected for evaluation, including operating income, advance receipts, per capita profit tax, assets, return on capital, and social contribution rate, as shown in Table 2.

Data of Table 2 from East Money Information (https://www.eastmoney.com/). The financial data of three representative listed highway lighting equipment suppliers in 2022 can be intuitively seen from Table II, showing the revenue situation of the three supplier enterprises.

Table 2. Index Evaluation

CN	OR	DR	PCPETP	Property	RAROC	SCR
A	16.86	16.86	−11.67	72.18	5.84	5.43
B	9.078	9.078	2.67	66.69	4.1	20.33
C	47.56	47.56	6.69	335.8	1.81	23.5

Note:

CN represents Corporate Name

OR represents Operating Revenue

DR represents Deposit Received

PCPETP represents Per Capita Profit Earnings and Tax Payment

SCR represents Social Contribution Rate

4.2 Analysis by combining evaluation methods

(1) Comprehensive index method

The calculation steps of the composite index method are as follows:

The first step is to record n as the number of evaluation objects and m as the number of indicators; x_{ij} is the j indicator value of the i object, n_j^+ is the number of objects with non-negative values for the j indicator, and n_j^- is the number of objects with negative values for the j indicator. Calculate the positive and negative mean values of x_j separately

$$\bar{x}_j^- = \frac{1}{n_j^-} \sum_{x_{ij}<0} x_{ij} \tag{1}$$

$$\bar{x}_j^+ = \frac{1}{n_j^+} \sum_{x_{ij}\geq 0} x_{ij} \tag{2}$$

The second step is to infinitely steel x_{ij} and call k_{ij} the conversion index of x_{ij}.

$$k_{ij} = \frac{x_{ij}}{\bar{x}_j^{+}} \times 100, x_{ij} \geq 0$$

$$k_{ij} = \frac{x_{ij}}{|\bar{x}_j^{-}|} \times 100, x_{ij} < 0$$

By calculation, the conversion index of various enterprise indicators can be obtained, as shown in Table 3.

Table 3. Conversion index of various enterprise indicators

CN	OR	DR	PCPETP	Property	RAROC	SCR
A	68.82	68.82	100	45.62	149.36	33.07
B	37.05	37.05	57.05	42.15	104.86	123.81
C	194.13	194.13	142.95	212.23	46.17	143.12

Step 3, take the average of the conversion indices for each indicator, and the comprehensive index ki is obtained as

$$k_i = \frac{1}{m} \sum_{j=1}^{m} k_{ij}, i = 1, 2, \ldots, n \tag{3}$$

By calculation, the comprehensive index of various enterprise indicators can be obtained, as shown in Table 4.

Table 4. Comprehensive index of various enterprise indicators

Serial Number	Enterprise	Composite Index	Sort
1	A	77.615	2
2	B	66.995	3
3	**C**	**155.455**	**1**

The comprehensive index method evaluation results are shown in Fig. 1. The comprehensive index method evaluation results for Enterprise A, Enterprise B, and Enterprise C are a, b, and c.

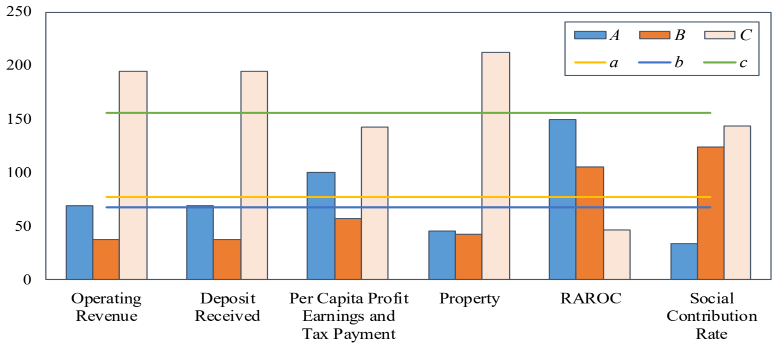

Fig. 1. Comprehensive Index Method Evaluation Results

(2) Queuing method based on estimated relative position scheme

Uses a queuing method based on estimating relative positions to rank three enterprises based on six indicators. Set three enterprises as (X_1, X_2, X_3), with operating income, accounts receivable, per capita profit tax, assets, return on capital, and social contribution rate as (Y_1, Y_2, Y_3, Y_4, Y_5, Y_6), and their weights set as $\omega = (0.2, 0.2, 0.1, 0.1, 0.2, 0.2)^T$, and now evaluate the three enterprises based on estimated relative positions.

The first step is to express the priority relationship of the plan.

Representing the scheme with a small circle is called a node; The directed arc represents the priority relationship, and the arrow starts from the node representing the optimal solution and points to the node representing the inferior solution. The rules for drawing directional graphs are set to

- If x_i is better than x_k, then the pointing arc starts from node x_i and points towards x_k;
- If x_i is equivalent to x_k, draw two directed arcs between x_i and x_k;
- If x_i and x_k are not comparable, then no directed arc is drawn between x_i and x_k.

The second step is to draw a 0-1 matrix representing the priority relationship based on the directional graph, with the assignment rule being

- If x_i is better than x_k, then p_{ik}=1 and p_{ki} =0;
- If x_i is equal to x_k, then p_{ik}= p_{ki} =1;
- If x_i is not comparable to xk, then p_{ik}= p_{ki} =0.

Usually, one priority relationship matrix and a directional graph can be given. The priority relationship matrix presented in this paper is shown in Tables 5 to 10.

Table 5. Scheme Comparison Priority Relationship Matrix Based on Y_1 Analysis

Programme	**1**	**2**	**3**
1	1	1	0
2	0	1	0
3	**1**	**1**	**1**

Table 6. Scheme Comparison Priority Relationship Matrix Based on Y_2 Analysis

Programme	**1**	**2**	**3**
1	1	1	0
2	0	1	0
3	**1**	**1**	**1**

Table 7. Scheme Comparison Priority Relationship Matrix Based on Y_3 Analysis

Programme	**1**	**2**	**3**
1	1	1	0
2	0	1	0
3	**1**	**1**	**1**

Table 8. Scheme Comparison Priority Relationship Matrix Based on Y_4 Analysis

Programme	**1**	**2**	**3**
1	1	1	0
2	0	1	0
3	**1**	**1**	**1**

Table 9. Scheme Comparison Priority Relationship Matrix Based on Y_5 Analysis

Programme	**1**	**2**	**3**
1	1	1	1
2	0	1	1
3	0	0	1

Table 10. Scheme Comparison Priority Relationship Matrix Based on Y_6 Analysis

Programme	**1**	**2**	**3**
1	1	0	1
2	1	1	1
3	**0**	**0**	**1**

The third step is to determine the overall priority relationship of each plan for (x_i, x_k).

Calculate the overall weight of the scheme for (x_i, x_k). Add the weights of each objective j of (x_i better than $x_k)_j$, denoted as $w(x_i$ better than x_k), similar to $w(x_i$ inferior to x_k), $w(x_i$ equal to or incomparable to x_k).

$$w(x_i \succ x_k) = \sum_{j \in (x_i \succ x_k)_j} w_j \tag{4}$$

$$w(x_i \prec x_k) = \sum_{j \in (x_i \prec x_k)_j} w_j \tag{5}$$

$$w(x_i \approx x_k) = \sum_{j \in (x_i \approx x_k)_j} w_j \tag{6}$$

The indication values of the overall superiority and inferiority of the calculation scheme for (x_i, x_k), where $1 \geq \sigma \geq 0$. The magnitude of the value σ reflects the importance of the objective of x_i and x_k being indistinguishable in the decision-making process.

$$A_\sigma(x_i, x_k) = \frac{w(x_i \succ x_k) + \sigma w(x_i \approx x_k)}{w(x_i \prec x_k) + \sigma w(x_i \approx x_k)} \tag{7}$$

From the analysis of Tables V to X, it can be concluded that the weight of X_1 over X_2 is A, and the weight of X_1 inferior to X_2 is 0.2.

The weight of X_1 over X_2 is 0.2 + 0.2 + 0.1 + 0.1 + 0.2 = 0.8, and the weight of X_1 inferior to X_2 is 0.2. Take A = 1.2, σ = 0, the overall quality index of the solution for (X_1, X_k) can be calculated as

$$A_\sigma(x_1,x_2)=\frac{w(x_1 \succ x_2)}{w(x_1 \prec x_2)}=\frac{0.8}{0.2}=4>1.2$$

The weight of X_1 over X_3 is 0.2 + 0.2 = 0.4, and the weight of X_1 is inferior to X_3. Take A = 1.2, σ = 0, the overall quality index of the solution for (X_1, X_k) can be calculated as

$$A_\sigma(x_1,x_3)=\frac{w(x_1 \succ x_3)}{w(x_1 \prec x_3)}=\frac{0.4}{0.6}=0.67<1.2$$

The weight of X_2 over X_3 is 0.2 + 0.2 = 0.4, and the weight of X_2 over X_3 is 0.2 + 0.2 + 0.1 +0.1 = 0.6. Take A = 1.2, σ = 0, the overall quality index of the solution for (X_1, X_k) can be calculated as

$$A_\sigma(x_2,x_3)=\frac{w(x_2 \succ x_3)}{w(x_2 \prec x_3)}=\frac{0.4}{0.6}=0.67<1.2$$

Select a threshold A ≥ 1 to determine the overall quality of the solution

- x_i is better than x_k, if $A_\sigma(x_i, x_k) \geq A$;
- x_i is equivalent or incomparable to x_k, if $1/A < A_\sigma(x_i, x_k) < A$;
- x_i is inferior to x_k, if $A_\sigma(x_i, x_k) \leq 1/A$;

The overall priority relationship matrix is shown in Table 11.

Table 11. Scheme Comparison Priority Relationship Matrix Based on Y6 Analysis

Programme	**1**	**2**	**3**
1	1	1	0
2	0	1	0
3	**1**	**1**	**1**

The fourth step of the plan is to calculate the queuing indicator value. The method for calculating the queuing indicator value is

$$v_i = r_i - q_i \tag{8}$$

Where r_i represents the number of directed arcs emitted from x_i, and q_i represents the number of directed arcs directed towards x_i. The larger the value of v_i, the better the scheme x_i. Based on the size of v_i, the advantages and disadvantages of each scheme in the scheme set can be determined.

$$v^* = \max\{v_i\} \tag{9}$$

Calculate $v_1 = 0$; $v_2 = -1$; $v_3 = 1$. Arrange the advantages and disadvantages of each scheme in the scheme set according to the size of V_i: $X_3 \succ X_1 \succ X_2$.

5 CONCLUSION

How to purchase high-quality products and services is an issue that highway operation companies attach great importance to, so the evaluation of equipment suppliers has become very important. Among them, the operation status of suppliers is an important indicator for evaluation. This article uses two comprehensive evaluation methods to establish a system indicator combination and evaluates the operations of three highway equipment suppliers from the perspectives of vertical calculation and horizontal comparison. This method provides a scientific basis for highway enterprises to choose suppliers. At the same time, this comprehensive evaluation method can help highway equipment procurement to have a more comprehensive understanding and evaluation of supplier development risks, and make correct decisions and choices.

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