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Selection of Equipment Tender Targets Model Based on Entropy Gray-Correlation Topsis Method

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Abstract. The entropy-gray-correlation-Topsis method is used to establish a tender target selection model. The model normalises indicator values and constructs indicator matrices for the number of people, proportion of professional staff, fixed assets, production infrastructure conditions, procurement contracts and return on assets of the enterprise, calculates the Euclidean distance and grey correlation between units and ideal and negative ideal solutions, analyses the primary indicator weight coefficients and secondary weight indices The final quantitative ranking is carried out to obtain the assessed values of the tenderee in terms of corporate strength, competitiveness, financial position and operational risk, and to select the tenderee with the best conditions. This model provides a reasonable and scientific evaluation index system for the selection of tenders.

Keywords. equipment tendering, entropy-gray-correlation-Topsis method, selection

1. Introduction

Due to its special commodity properties, military equipment has more stringent requirements on quality, technology and performance, and for quite a long period of time, only the relevant enterprises have undertaken the task of development and production. With the deepening of the reform of the socialist market economy and the participation of civil enterprises in military equipment projects, the use of bidding for military equipment procurement by relevant units has gradually become the mainstream of development. The calculation of the tender selection model can deepen the understanding of the procurement of weapons and equipment, help to improve the quality of the tender and procurement quotation, and promote the healthy development of the industry[1-4].

Selection can be interpreted as a deliberate way to choose, selection or selection process, tender selection is a more rigorous form of tender selection to meet the requirements of the tender procurement range of suppliers, to provide the basis for the selection of equipment tender to the scientific quantification and standardization of the direction of development, to support the management of the organ tender decision, truly

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responsible for the bidding unit, socially responsible, for the bidding unit is also It is also more fair to the bidding units and is conducive to the selection of the most suitable cooperation unit.

The equipment bidding target selection model builds a supplier capability evaluation index system according to the bidding and procurement requirements of equipment projects, quantifies and ranks the suppliers in the contract database, and complies with the selection of suppliers that meet the bidding and procurement requirements to support the management decisions of the organ's bidding work. The selection of suppliers is based on the characteristics of suppliers under the lean concept, combined with the needs of the military industry, emphasizing the selection of excellent suppliers from a strategic perspective of long-term cooperation, and building lean supply relationships. The core is the establishment of a supplier capability evaluation index system[5].

Equipment bidding object compliance selection is conducive to the realization of refined management of the whole life cycle of weapons and equipment, is an important link in the development and production, retrofitting, maintenance and other stages, and is a key object for quality supervision and capital efficiency assessment. However, in recent years, the military industry has focused on the selection of bidding objects on the assessment of individual business modules of suppliers, and the evaluation criteria are relatively single and discrete, with less involvement in the evaluation of the comprehensive capability of suppliers in the selection of bidding objects. If the evaluation of the comprehensive ability of suppliers is to be realized, a set of more relevant and perfect supplier evaluation index system is needed. It can be useful in terms of cost reduction and quality optimization[6-9].

In information theory, the entropy value can well reflect the degree of information disorder. The smaller the value, the lower the system disorder, the higher the utility value of information and the correspondingly higher its weight; conversely, the larger the value, the higher the system disorder, the lower the utility value of information and the lower its weight.

Grey System Theory is a system science theory pioneered by the renowned scholar Professor Deng Julong, in which Grey Correlation Analysis (GRA) is a multi-factor statistical analysis method. In simple terms, it means that in a grey system we want to know the relative strength of an item we are concerned about in relation to other factors. By analogy, ranking these factors and getting a result of the analysis, we can know which of the factors are more relevant for the indicator we are concerned with. Grey systems theory is based on the study of "information-poor" uncertainty systems where some of the information is known and some is not, using known information to determine the unknown information about the system. The basic idea of grey correlation analysis is to determine whether a sequence is closely linked based on the similarity of its curve geometry. The closer the curves are, the greater the degree of correlation between the corresponding series and vice versa. It is the basis for grey system analysis, rating and decision making. The basic idea is to determine whether two indicators are closely related to each other based on the degree of similarity in the geometry of the series curves presented by the data indicators. It is equally applicable to the size of the sample and the presence or absence of a pattern in the sample, and is easy to calculate with little effort, not to mention the fact that the quantitative results do not match the results of the qualitative analysis. The degree of association between two things is characterised by the degree of correlation General abstract systems, such as social systems, economic systems, agricultural systems, ecosystems, educational systems, etc. contain many kinds, and the result of a combination of factors determines the development of the system's dynamics. Grey correlation analysis is then used to determine the degree of influence of each factor on the system in which it is located [10-13].

The TOPSIS method is one of the classical multi-indicator decisions making methods and has been widely used in evaluation studies, particularly noteworthy is the application of the TOPSIS method to assess risk. TOPSIS is a method for order preference by similarity to an ideal solution, and is a comprehensive distance evaluation method. The basic idea is to assume positive and negative ideal solutions, measure the distance between each sample and the positive and negative ideal solutions, and obtain the relative closeness to the ideal solution (i.e. the closer the positive ideal solution is to the negative ideal solution, the further it is to the negative ideal solution), and then rank the evaluation objects in order of merit. The results accurately reflect the differences between the evaluation solutions. The basic process is to find the optimal and inferior solutions among the finite solutions using the cosine method based on the normalized original data matrix, and then calculate the distance between each evaluation object and the optimal and inferior solutions respectively to obtain the relative proximity of each evaluation object to the optimal solution, which is used as the basis for evaluating the superiority and inferiority [14-23].

After considering the above analysis methods, this paper proposes a tender selection model based on entropy-grey correlation-TOPSIS, by establishing an index system, using entropy-grey correlation-TOPSIS method to analyze the evaluation data, the supply enterprises "enterprise strength", " financial status" to provide a scientific basis for future cooperation with enterprises and to continuously improve the level of material supply, distribution and management.

2. Principle of the Algorithm

A scientific evaluation index system for equipment ordering contract bidding objects was constructed, the analytic hierarchy method was used to determine the weight coefficient of each first-level index system, and the entropy weight-grey association-Topsis method was used to establish the weight of the second-level indicators of "enterprise strength" and "financial status", and the evaluation value of the first-level index was calculated to obtain the comprehensive evaluation value. The specific steps are as follows:

2.1 Normalized Indicator Values

1) Constructing a matrix of indicators

There are m units to be assessed, containing n assessment indicators with corresponding indicator values of $a_{ij}(i = 1,2,\cdots,, j = 1,2,\cdots, n)$ and an indicator matrix of $A = \left(a_{ij}\right)_{m\times n}$.

2) Indicator matrix normalization

Due to the different nature of the assessment indicators, they need to be normalised to eliminate the influence of different physical scales on the assessment results.

For positive indicators, an affiliation function is used:

$$b_{ij} = \frac{a_{ij}}{a^{j}_{\max}}, i = 1,2,\cdots,m \tag{1}$$

Where: $a_{\max}^{j} = \max\limits_{1 \le i \le m}\{a_{ij}\},\ j = 1,2,\cdots,n$.

For negative indicators, an affiliation function is used:

$$b_{ij} = 1 + \frac{a_{\min}^{j}}{a_{\max}^{j}} - \frac{a_{ij}}{a_{\max}^{j}},\ i = 1,2,\cdots,m \tag{2}$$

Where: $a_{\min}^{j} = \min\limits_{1 \le i \le m}\{a_{ij}\},\ j = 1,2,\cdots,n$.

Denote the dimensionless indicator matrix after processing as $B = (b_{ij})_{m \times n}$.

3) Normalisation

Normalize the matrix B to obtain the matrix $C = (c_{ij})_{m \times n}$ where $c_{ij} = b_{ij} / \sum\limits_{i=1}^{m} b_{ij}$.

4) Determine the weight of each indicator using the entropy weighting method

Define the entropy value of the j indicator as:

$$E_j = \frac{1}{\ln m}\sum_{i=1}^{m} c_{ij} \ln c_{ij} \tag{3}$$

The entropy weight of the j indicator is then:

$$\omega_j = (1 - E_j) / \sum_{k=1}^{n}(1 - E_k) \tag{4}$$

Where: $\sum\limits_{j=1}^{n} \omega_j = 1, 0 \le \omega_j \le 1$.

5) Weighted standardisation of the indicator matrix

Multiply the normalised indicator matrix with the corresponding indicator weights to obtain the weighted normalised decision matrix:

$$Z_{ij} = (z_{ij})_{m \times n} = (b_{ij}\omega_j)_{m \times n} \tag{5}$$

2.2 Determination of Ideal and Negative Ideal Solutions and Grey Correlation

The Euclidean distance and grey correlation between each unit and the ideal and negative ideal solutions are calculated separately.

1) Ideal and negative ideal solutions

$$Z^{+} = \{\max_{1 \le i \le n} Z_{ij}\} = [z_1^{+}, z_2^{+}, \cdots, z_n^{+}] \tag{6}$$

$$Z^{-} = \{\min_{1\le i\le n} Z_{ij}\} = [z_1^{-}, z_2^{-}, \cdots, z_n^{-}] \tag{7}$$

2) Calculate the Euclidean distance from each unit to the ideal solution and the negative ideal solution as d_i^{+} and d_i^{-} respectively, then

$$d_i^{+} = \sqrt{\sum_{j=1}^{n} (z_{ij} - z_j^{+})^2}, i = 1,2, \cdots, m \tag{8}$$

$$d_i^{-} = \sqrt{\sum_{j=1}^{n} (z_{ij} - z_j^{-})^2}, i = 1,2, \cdots, m \tag{9}$$

3) Calculate the number of grey correlation coefficients between each unit and the ideal and negative ideal solutions as R^{+} and R^{-}, where

$$R^{+} = (r_{ij}^{+})_{m\times n}, \quad R^{-} = (r_{ij}^{-})_{m\times n} \tag{10}$$

$$r_{ij}^{+} = \frac{\min_i \min_j | z_j^{+} - z_{ij} | + \rho \max_i \max_j | z_j^{+} - z_{ij} |}{| z_j^{+} - z_{ij} | + \rho \max_i \max_j | z_j^{+} - z_{ij} |} \tag{11}$$

$$r_{ij}^{-} = \frac{\min_i \min_j | z_j^{-} - z_{ij} | + \rho \max_i \max_j | z_j^{-} - z_{ij} |}{| z_j^{-} - z_{ij} | + \rho \max_i \max_j | z_j^{-} - z_{ij} |} \tag{12}$$

Where: $\min_i \min_j | z_j^{+} - z_{ij} |$, $\min_i \min_j | z_j^{-} - z_{ij} |$ and $\max_i \max_j | z_j^{+} - z_{ij} |$, $\max_i \max_j | z_j^{-} - z_{ij} |$ are the two levels of minimum and maximum differences respectively, and $\rho \in [0,1]$ is the resolution factor, generally taken as 0.5.

4) Calculate the grey correlation between each unit and the ideal and negative ideal solutions respectively as

$$r_i^{+} = \frac{1}{n} \sum_{j=1}^{n} r_{ij}^{+}, i = 1,2, \cdots, m \tag{13}$$

$$r_i^{-} = \frac{1}{n} \sum_{j=1}^{n} r_{ij}^{-}, i = 1,2, \cdots, m \tag{14}$$

2.3 Calculate relative closeness to achieve quantitative ranking

1) Euclidean distances d_i^+, d_i^- and grey correlations r_i^+, r_i^- are dimensionless respectively

$$\varphi_i^+ = \frac{\Phi_i^+}{\max_i \Phi_i^+}, i = 1,2,\cdots,m \tag{15}$$

Where: Φ_i^+ stands for d_i^+, d_i^- and r_i^+, r_i^- obtained as

$$D_i^+ = \frac{d_i^+}{\max_i d_i^+}, D_i^- = \frac{d_i^-}{\max_i d_i^-} \tag{16}$$

$$R_i^+ = \frac{r_i^+}{\max_i r_i^+}, R_i^- = \frac{r_i^-}{\max_i r_i^-} \tag{17}$$

2) Using the entropy weighting method, the dimensionless Euclidean distance and the grey correlation are integrated. Since the larger the values of D_i^- and R_i^+, the closer to the ideal solution, and the larger the values of D_i^+ and R_i^-, the further away from the ideal solution, note that

$$S_i^+ = \alpha_1 D_i^- + \beta_1 R_i^+, \quad i = 1,2,\cdots m \tag{18}$$

$$S_i^- = \alpha_2 D_i^+ + \beta_2 R_i^-, \quad i = 1,2,\cdots m \tag{19}$$

where $\alpha_1 + \beta_1 = 1, \alpha_2 + \beta_2 = 1$ and $\alpha_1, \beta_1, \alpha_2, \beta_2 \in [0,1]$, reflecting the degree of preference, are determined using the entropy weighting method, respectively S_i^+. The composite reflects the degree of closeness of the unit to the ideal solution, the higher its value, the higher the capacity, and S_i^- the composite reflects the degree of distance of the unit from the ideal solution, the higher its value, the lower the capacity.

3) Calculation of relative closeness

The relative closeness reflects the closeness of each unit to the ideal solution of the living negative ideal:

$$C_i^+ = \frac{S_i^+}{S_i^+ + S_i^-}, i = 1,2,\cdots,m \tag{20}$$

Where, C_i^+ is the relative closeness.

3. Tender System

The selection of equipment bidding objects selects enterprise strength, enterprise competitiveness, financial status and credit risk as the first-level indicators, among which, enterprise strength includes the number of enterprises, the proportion of professional and technical personnel, business income in the previous year, fixed assets, production infrastructure conditions, the ability to guarantee infrastructure conditions related to the procurement content, the ratio of R&D expenses and the number of intellectual property rights related to the last three years; Enterprise competitiveness includes the contract amount related to the procurement content in the past three years, the number of contracts related to the procurement content in the past three years, and the contract evaluation related to the procurement content in the past three years; financial status includes gearing ratio, return on net assets, total assets turnover ratio, sales (operating) growth rate, capital preservation and appreciation ratio, and quick ratio; credit risk includes credit rating and non-performing information, as shown in Table 1.

Table 1. Table of indicators for the selection of equipment tender targets

Serial number	Level 1 indicators	Level 2 indicators
1	Corporate Strength	Number of companies
2		Proportion of professional and technical staff
3		Prior year operating income
4		Fixed assets
5		Production infrastructure
6		Infrastructure capacity in relation to the content of the procurement
7		R&D cost ratio
8		Number of relevant IPRs in the last three years
9	Corporate Competitive-ness	Contract value related to the content of the procurement in the last three years
10		Number of contracts related to the content of the procurement in the last three years
11		Evaluation of contracts related to the content of the procurement in the last three years
12	Financial position	Gearing ratio
13		Return on net assets
14		Total asset turnover ratio
15		Sales (operating) growth rate
16		Capital preservation and appreciation rate
17		Quick ratio
18	Credit risk	Credit rating
19		Adverse Information

4. Simulation Flow Chart

The equipment tender object selection model flow is shown in Figure 1.

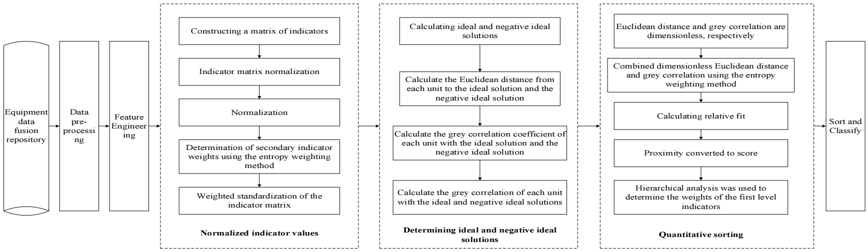

Figure 1 Flow chart of the equipment tender object selection model

5. Example Analysis

As an example, see Table 2 for data on the strength of each tender target for ordering a particular type of equipment.

Table 2. Data sheet for equipment tender recipients

Serial number	Indicators	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
1	Number of companies	5199	10206	8124	6726	6893	9068	10610	10906	6017	11749
2	Proportion of professional and technical staff	75.95	81.22	81.21	88.22	76.87	87.2	80.48	77.74	79.91	83.27
3	Prior year operating income	55.43	79.57	72.68	95.02	92.73	63.81	66.95	88.69	50.11	91.53
4	Fixed assets	197.69	213.68	245.14	179.16	269.17	189.46	217.05	264.8	277.24	273.38
5	Production infrastructure	86.67	94.96	90.89	89.61	94.04	91.65	85.2	90.6	92.51	94.01
6	Infrastructure capacity in relation to the content of the procurement	79.32	96.57	96.44	81.36	83.97	84.63	78.34	90.81	81.1	84.51
7	R&D cost ratio	0.046	0.038	0.025	0.032	0.042	0.039	0.048	0.022	0.028	0.035
8	Number of relevant IPRs in the last three years	5	4	5	3	4	3	4	2	3	5
9	Contract value related to the content of the procurement in the last three years	15.28	21.66	21.81	14.39	15.72	22.1	26.94	25.22	17.65	26.03
10	Number of contracts related to the content of the procurement in the last three years	29	22	28	17	23	29	32	31	29	33

11	Evaluation of contracts related to the content of the procurement in the last three years	84.39	89.13	90.98	90.19	90.74	93.31	89.91	91.15	93.85	84.59
12	Gearing ratio	0.6359	0.5598	0.6467	0.6209	0.4815	0.5211	0.5704	0.6423	0.6487	0.6253
13	Return on net assets	0.0803	0.0653	0.0738	0.0702	0.0811	0.0766	0.0643	0.0639	0.0762	0.0752
14	Total asset turnover ratio	0.0698	0.0662	0.0552	0.0617	0.0722	0.0709	0.054	0.0689	0.0652	0.0624
15	Sales (operating) growth rate	0.1186	0.1305	0.1289	0.1348	0.117	0.1314	0.1349	0.1151	0.1263	0.1238
16	Capital preservation and appreciation rate	117.83	110.02	107	110.46	113.35	108.9	107.83	110.08	113.44	106.2
17	Quick ratio	0.8079	0.9494	0.8627	0.8493	0.9122	0.9128	0.9104	0.8938	0.8423	0.9042
18	Credit rating	90	80	95	75	80	95	85	90	95	90
19	Adverse Information	6	9	8	7	5	8	3	9	4	8

A hierarchical analysis was used to determine the weighting factors for the first level indicators as shown in table 3.

Table 3. Table of weighting coefficients for indicators at the level of the equipment tender target

Serial number	Indicators	Weighting factor
1	Corporate Strength	0.30
2	Corporate Competitiveness	0.25
3	Financial position	0.25
4	Credit risk	0.20

The entropy-gray correlation-Topsis method was used to establish the weights of the secondary indicators of "enterprise strength", "enterprise competitiveness", "financial status" and "credit risk", respectively. The weights of the secondary indicators of the indicators of "credit risk" and the assessment values of the primary indicators were calculated and the results were obtained as shown in table 4.

Table 4. Table of results of the calculation of the first level of indicators for equipment tenders

Serial number	Company	Corporate Strength	Corporate Competitiveness	Financial position	Credit risk
1	C1	90	85	90	92
2	C2	95	88	91	84
3	C3	91	92	85	86
4	C4	84	76	87	89
5	C5	91	82	100	95
6	C6	87	93	98	86
7	C7	97	100	87	100
8	C8	85	98	88	84
9	C9	80	87	88	97
10	C10	100	99	88	86

The summary calculation for each level of indicators gives as shown in table 5 and Figure 2.

Table 5. Combined score table for equipment tender recipients

Serial number	Company	Score	Ranking
1	C1	89.15	6
2	C2	90.05	5
3	C3	88.75	8
4	C4	83.75	10
5	C5	91.80	3
6	C6	91.05	4
7	C7	95.85	1
8	C8	88.80	7
9	C9	87.15	9
10	C10	93.95	2

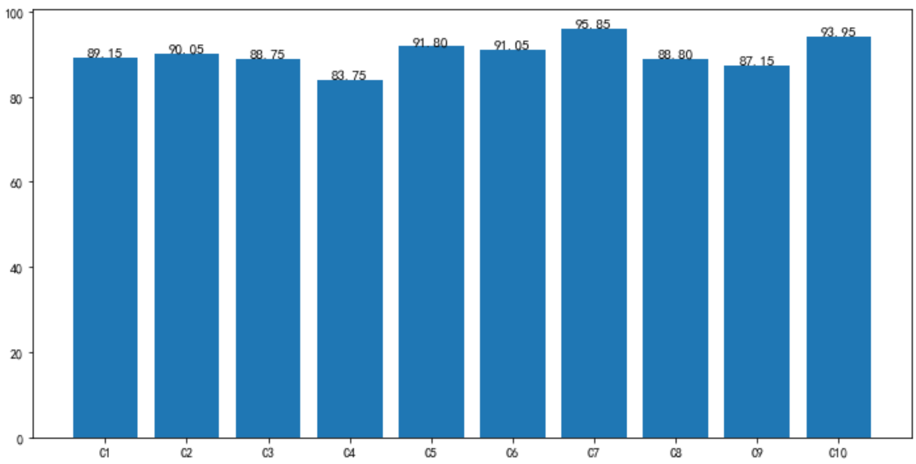

Figure 2 Histogram of strength scores for each tender target

As can be seen, C7 is the strongest.

6. Conclusion

In order to improve the evaluation efficiency of bidding enterprises and ensure the quality of equipment bidding, this paper uses the entropy-weighted-grey correlation-Topsis method to establish a bidding selection model, with input parameters including staffing, revenue and assets, production infrastructure conditions and R&D cost ratio, etc. By solving for the positive and negative ideal values of each index, calculating the degree of fit and ranking quantitatively, and analysing its performance in terms of enterprise examples, competitiveness, financial position, credit risk and other indicators, and finally simulate to obtain the comprehensive competitive ability of the bidding enterprise. Based on this model an accurate and reasonable evaluation system provides a scientific basis for future cooperation with enterprises.

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