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A Comprehensive Evaluation Model of Military Equipment Contractor Capacity Based on Grey Target Decision Theory

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Abstract. It's difficult to obtain and standardize the contractor capacity information during the process of the military equipment contractor evaluation. This paper analyzed 8 main influencing factors of contractor capacity and established a comprehensive evaluation model of military equipment contractor capacity based on grey target decision theory. Taking the military software production and development project as an example, the evaluation model was used to evaluate the capacity of five contractors, and the effectiveness of the model was verified. The evaluation model realized the comprehensive evaluation of the qualified influencing factors of the contractor capacity, and put forward an effective method to evaluate contractor capacity under the limited sample information situation.

Keywords: military equipment, contractor capacity, grey target decision theory, mathematical modeling.

1. Introduction

The comprehensive evaluation of military equipment contractor capacity is conducive to the selection of ideal equipment contractor by the military, and is of great significance to improving the quality of equipment products, improving the efficiency of equipment development, and promoting the production management level of contractors.

Chinese scholars have made some theoretical achievements in the study of military equipment contractor capacity evaluation. Jian-jun Wang, Wei-wei Wu and Lei Yang analyzed and summarized the factors restricting contractor qualification review, pointed out that to evaluate the contractor capacity, the focus of the existing method of policy is unqualified factor, lack of effective comprehensive evaluation method [1]. Aiming at the evaluation index system of naval vessel contractors, Yun SUN established the evaluation system of naval vessel contractors from the aspects of quality, cost, delivery time, technology, service, financial management and social responsibility [2]. Wei Wei and Shuai Zhao established the evaluation index system of military equipment contractors' quality and reputation, and established detailed hierarchy index and index weight [3].

In this paper, grey target decision theory is used to evaluate the military equipment contractor capacity. In this method, the optimal values of all indexes are selected as the bull's eye sequence, and the measured values are synthetically sorted according to the deviation degree between the measured values and the bull's eye. The selection of the bull's eye can be set and adjusted according to different decision targets, which has great flexibility.

Moreover, grey target decision method requires less data sample size, so it is suitable for small and poor information samples [4]. Considering that it is difficult to obtain and quantify the full sample information of military equipment contractor capacity, it is appropriate to use grey target decision theory to evaluate the military contractor capacity. Expert method is applied to score the factors affecting the contractor capacity, realizes quantitative evaluation of the qualified factors of the contractors.

2. Factors affecting military equipment contractor capacity

On the basis of the existing study, combined with the actual work background of the comprehensive evaluation of military equipment contractor capacity, especially the limited contractor capacity information acquisition situations, 8 main influencing factors are screened out and the comprehensive evaluation index system of contractor capacity is established.

2.1. Equipment product quality

Product quality refers to the ability of the product to meet explicit and implicit needs of the entity. The inspection of the quality of military equipment can be carried out through the review of quality management system operating documents of the contractor and the random sampling test of products. The implementation of quality management system operating documents and the product sampling test results are scored by the experts to evaluate equipment product quality of the contractor. As the product quality is the core attribute of military equipment, the military usually requires the equipment products have the highest quality in the evaluation of the contractor capacity.

2.2. On-time delivery capacity

The on-time delivery capacity of contractor is the key index of project acceptance. On the premise of ensuring the quality of equipment products to meet the requirements, the shorter time the project takes the stronger on-time delivery capacity the contractor has. The on-time delivery rate of the contractor and the product delivery contingency plan are scored by the experts to evaluate on-time delivery capacity of the contractor. The military usually requires a high level of on-time delivery capacity from the contractor.

2.3. Technical capacities

The mass production of equipment not only requires the contractor to have product quality assurance and on-time delivery capacity, but also requires the contractor to have technical capacities of designing, production and processing that meet the requirements of the military. The configuration of the production equipment and the setting of the production process are scored by the experts to evaluate the technical capacities of the contractor. According to the requirements of specific equipment production and development tasks, the military puts forward corresponding requirements on the technical capacities of the contractor.

2.4. Human resources

The purpose of management is to get assigned work done by other people. As the influencing factors of the contractor capacity, the personnel capacity and manpower management capacity should be included in the comprehensive assessment system of contractor capacity. Through the number and structure of technical personnel, management system of the contractor as well as personnel capacity and qualification certificate for review, human resources of the contractor are scored by the experts for evaluation. According to the specific requirements of equipment production and development tasks, the military puts forward corresponding requirements on the human resources of the contractor.

2.5. Secrecy

Due to the purpose of operation and the technical standard of military equipment, the production and development of military equipment usually require the contractor to be absolutely confidential. Through the review of the confidentiality qualification certificate of the contractor, secrecy of the contractor is scored by the experts for evaluation. The military usually requires the highest level of secrecy from the contractor.

2.6. Independent innovation capacity

In the field of military equipment, the capacity of independent innovation is an important prerequisite for equipment upgrading. Through the review of key technology, new materials and other innovative applications of the contractor, independent innovation capacity of the contractor is scored by the experts for evaluation. According to the specific requirements of equipment production and development tasks, the military puts forward corresponding requirements on the independent innovation capacity of the contractor.

2.7. Environmental protection capacity

Protecting the environment is a basic state policy of China. The military equipment industry, as the basic industry of China, also has the responsibility and obligation to protect the environment. Through the review of the environmental responsibility statement, environmental management system, monitoring of pollutants and emergency pollution rescue mechanism of the contractor, environmental protection capacity is scored by the experts for evaluation. According to the requirements of specific equipment production and development tasks, the military puts forward corresponding requirements on the environmental protection capacity of the contractor.

2.8. Cost saving capacity

As the basis of equipment price, cost is generally required to be reduced as much as possible on the premise that the equipment meets the design performance index. Evaluate the cost saving capacity of different contractors by comparing their product prices and the comparison against the market mean. The military usually requires a high level of cost-saving capacity from the contractor.

3. A comprehensive evaluation method of contractor capacity based on grey target decision theory

According to the 8 main influencing factors of contractor capacity, a comprehensive evaluation model of contractor capacity based on grey target decision theory is presented.

The grey target decision theory was first proposed by professor Ju-long DENG, founder of the grey theory, whose basic idea is to find the target value data closest to the sub-proposition from a group of pattern sequences and construct the standard model under the condition that the decision model contains grey elements or the general decision model is combined with the grey model. Each model and the standard model together constitute the grey target, the standard model is the bull's eye, and the gray correlation degree between the model and the bull's eye in each grey correlation information space is called the bull's eye proximity. Aiming at the multi-objective grey target decision-making model of interval grey number, the multi-level problem is simplified into a single-level problem by aggregating the index information under each target [5].

In this paper, the comprehensive evaluation of military equipment capacity is regarded as an event, denoted as

$$\mathrm{A} = \{\mathrm{a}_1\} \tag{1}$$

Take *m* potential contractors as the game set, denoted as

$$B = \{b_1, b_2 \cdots b_m\} \tag{2}$$

where in, $b_i(\mathrm{i} = 1, 2, \cdots \mathrm{m})$ means to use grey target decision theory to comprehensively evaluate the capacity of the contractor *i*.

The situation set is denoted as

$$\mathrm{S} = \mathrm{A} \times \mathrm{B} = \{\mathrm{s}_{1\mathrm{i}} = (\mathrm{a}_1, \mathrm{b}_\mathrm{i}) \mid \mathrm{a}_\mathrm{i} \in \mathrm{A}, \mathrm{b}_\mathrm{i} \in \mathrm{B}\} \tag{3}$$

The sample value of effect on factor k in situation s_{1i} is $u_{1i}^{(k)}(i = 1, 2, \cdots m;\ k = 1, 2, \cdots)$, which means the scores of experts on influencing factor *k*. The effect sample matrix of situation set *S* with respect to influencing factor *k* is

$$U^{(k)} = \left[u_{1i}^{(k)}\right] = \left[u_{11}^{(k)}\ u_{12}^{(k)}\ \cdots\ u_{1m}^{(k)}\right] \tag{4}$$

In order to eliminate the differences of different dimensions, increase the comparability of different types of data, the effect measure of influencing factors is established. The influencing factors are divided into three categories, namely benefit type factors, cost type factors and moderate type factors. Benefit type factor, using upper limit effect measure; Cost type factor, using lower limit effect measure; Moderate type factor, using moderate effect measure. The calculation formulas of bull's eye distance for different types of influencing factors are shown as follows.

3.1. The bull's eye distance with upper limit effect measure:

$$r_{1i}^{(k)} = \frac{u_{1i}^{(k)}}{max_i\left\{u_{1i}^{(k)}\right\}} \tag{5}$$

The upper limit effect measure reflects the deviation between the effect sample value and the maximum effect sample value.

3.2. The bull's eye distance with lower limit effect measure:

$$r_{1i}^{(k)} = \frac{\min_i\left\{u_{1i}^{(k)}\right\}}{u_{1i}^{(k)}} \tag{6}$$

The lower limit effect measure reflects the deviation between the effect sample value and the minimum effect sample value.

3.3. The bull's eye distance with moderate effect measure:

$$r_{1i}^{(k)} = \frac{u_{1i_0}^{(k)}}{u_{1i_0}^{(k)} + \left|u_{1i}^{(k)} - u_{1i_0}^{(k)}\right|} \tag{7}$$

In this paper, $u_{1i_0}^{(k)}$ takes the effect sample mean of the influencing factor *k*.

The above three effect measures should be satisfied

1) $r_{1i}^{(k)}$ is dimensionless.
2) $r_{1i}^{(k)} \in [0, 1]$.
3) The larger the value of $r_{1i}^{(k)}$, the better the result.

Through the effect measure formula, the bull's eye deviation degree of each contractor capacity influencing factor can be calculated, the uniform effect measure matrix of situation set S to influencing factor *k* is

$$R^{(k)} = \left[r_{1i}^{(k)}\right] = \left[r_{11}^{(k)}\ r_{12}^{(k)}\ \cdots\ r_{1m}^{(k)}\right] \tag{8}$$

By synthetic processing of the uniform effect matrix, a comparable synthetic effect measure matrix can be obtained. The weighted method is adopted for calculation. Firstly, the weight value of the influencing factor of ability is determined, $n_k\ (k = 1, 2, \cdots 10)$ is denoted as the weight of the influencing factor *k*, satisfying $\sum_{k=1}^{10} n_k = 1$. Then the synthetic effect measure of situation *s* is

$$r_{1i} = \sum_{k=1}^{10} n_k \cdot r_{1i}^{(k)} \tag{9}$$

The above formula is the comprehensive score of military equipment contractor capacity of contractor i. According to the size of the comprehensive score, the contractors are sorted to achieve the comparison of contractor capacity.

4. Calculation example

It is known that military wants to purchase an application software for the combat training of a certain service. There are 5 contractors meeting the basic requirements of military software development and production, use the comprehensive evaluation model described in this paper to evaluate the military software contractor capacity of five contractors.

The military's request for the task is for the contractors to develop a windows 7 platform application that would meet the simulation training needs of a service. The contractor is required to develop independently, strictly abide by the confidentiality provisions on the development and production of military equipment, save costs to the greatest extent on the premise of ensuring the quality of the software, and strictly deliver the products within the time limit stipulated in the contract. The contractor should have the capacity of mass production of optical disks and take effective environmental protection measures in the process of software development and production.

The expert method is used to score the 7 factors influencing the capacity of 5 contractors, and the expert set is 10 experts in the field of software production and development (the factor of cost saving capacity is not scored by experts). The expert scores are scored on a 10-point scale. For each influencing factor, five rating comment sets are divided. The corresponding interval of "ideal" is 8-10 points; the corresponding interval of "better" is 6-8 points; the corresponding interval of "qualified" is 4-6 points; the corresponding interval of "poor" is 2-4 points; and the corresponding interval of "unqualified" is 0-2 points. Within each fractional interval, 0.4 points is divided into step values and divided into 5 subintervals. The final score of each factor is averaged by 10 experts. For the cost saving capacity factor, the input value is the cost budget of the contractor.

The comprehensive evaluation of the military software development and production contractor capacity is regarded as an event, then the event set is $A = \{a_1\}$. The 5 contractors are denoted as b_1, b_2, b_3, b_4, b_5, then the game set is $B = \{b_1, b_2, \cdots b_5\}$. The situation set constituted by event set A and game set B is $S = A \times B = \{s_{1i} = (a_1, b_i) \mid b_i \in B, i = 1, 2, \cdots 5\} = \{s_{11,} s_{12,} \cdots s_{15}\}$.

8 contractor capacity influencing factors and weight values obtained by the expert method are given, as shown in table 1.

Table 1. Influencing factors and weights of contractor capacity.

	Influencing factor	Factor weight	Factor type
k_1	Equipment product quality	0.14	Benefit
k_2	On-time delivery	0.12	Benefit
k_3	Secrecy	0.13	Benefit
k_4	Independent innovation	0.14	Benefit
k_5	Technical capacities	0.11	Moderate
k_6	Human resources	0.11	Moderate
k_7	Environmental protection	0.11	Moderate
k_8	Cost saving	0.14	Cost

The average scores of the experts and the cost budget are shown in table 2.

Table 2. Scores of influencing factors and cost budget k_8 (cost budget unit: RMB 10,000).

	k_1	k_2	k_3	k_4	k_5	k_6	k_7	k_8
b_1	9.8	9.8	9.6	8.9	8.8	9.7	8.3	95
b_2	9.5	9.6	9.8	9.5	9.6	8.6	9.6	90
b_3	9.8	9.8	9.8	9.2	8.8	8.7	9.3	100
b_4	8.6	8.6	8.5	7.6	8.6	9.3	8.4	85
b_5	9.2	8.8	9.6	7.3	7.3	8.3	7.4	85

Through the data in table 2, the effect sample vectors of each influencing factor are obtained, as shown in table 3.

Table 3. Effect sample vectors.

	$U^{(1)}$	$U^{(2)}$	$U^{(3)}$	$U^{(4)}$	$U^{(5)}$	$U^{(6)}$	$U^{(7)}$	$U^{(8)}$
s_{11}	9.8	9.8	9.6	8.9	8.8	9.7	7.5	95
s_{12}	9.5	9.6	9.8	9.5	9.6	8.6	9.6	90
s_{13}	9.8	9.8	9.8	9.2	8.8	8.7	9.3	100
s_{14}	8.6	8.6	8.5	7.6	8.6	9.3	8.4	85
s_{15}	9.2	8.8	9.6	7.3	7.3	8.3	7.4	85

According to the data in table 3, formula (5), (6) and (7) are used to calculate the uniform effect measure matrix, as shown in table 4.

Table 4. Uniform effect measure matrix.

	$R^{(1)}$	$R^{(2)}$	$R^{(3)}$	$R^{(4)}$	$R^{(5)}$	$R^{(6)}$	$R^{(7)}$	$R^{(8)}$
s_{11}	1.00	1.00	0.98	0.94	0.98	0.93	0.97	0.89
s_{12}	0.97	0.98	1.00	1.00	0.91	0.96	0.91	0.94
s_{13}	1.00	1.00	1.00	0.97	0.98	0.98	0.93	0.85
s_{14}	0.88	0.88	0.87	0.80	1.00	0.96	0.98	1.00
s_{15}	0.94	0.90	0.98	0.77	0.85	0.93	0.86	1.00

Through the data in table 4, formula (9) is used to calculate the synthetic effect measure matrix *R*, as shown in table 5.

Table 5. Synthetic effect measure matrix R.

	s_{11}	s_{12}	s_{13}	s_{14}	s_{15}
R	0.960	0.961	0.962	0.916	0.904

Through the synthetic effect measure matrix, the ordering of the military software contractor capacity of 5 contractors is $b_3 > b_2 > b_1 > b_4 > b_5$, that is, contractor b_3 has the highest comprehensive evaluation of the contractor capacity. According to the uniform effect measure matrix, contractor b_3 has the highest score for equipment product quality, on-time delivery capacity and secrecy. For the three moderate factors contractor b_3 also has moderate scores. Contractor b_3 has the highest cost budget among the five contractors, and it ranks last in the cost saving capacity. Considering the weight of influential factors given by experts and the influence of various factors, b_3 is still the ideal contractor of the project.

5. Results analysis

Based on existing theoretical research of military equipment contractor capacity evaluation, this paper analyzed 8 main factors that affect the contractor capacity, and established a comprehensive evaluation model of contractor capacity based on the grey target decision theory. The comprehensive evaluation model was applied to the calculation and analysis of military software project, and the ideal contractor of the project was obtained.

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