Research on Weapon Equipment Purchase Performance Evaluation Based on Support Vector Machine

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Abstract. In this paper, we present an efficient performance evaluation method of weapon equipment purchase based on support vector machine. Firstly, the concept of weapon equipment purchase performance evaluation was explained and the existing problems of weapon equipment purchase performance evaluation were analysed. Then, a 12-dimension performance evaluation indicator system was constructed (these dimensions are: budget progress, cost-benefit ratio, expenditures reduction rate, supplier satisfaction, purchaser satisfaction, customer satisfaction, purchase cycle rationality, qualification rate, price rationality, competition, success rate, and policy completeness). And lastly, a weapon equipment purchase performance evaluation model based on support vector machine was established, and a case analysis was conducted. The result provides a reference for building the indicator system and model for weapon equipment purchase performance evaluation and the research conclusion can help complete and improve the evaluation method.

1. Introduction

Weapon equipment purchase performance evaluation is a guideline and an essential method to measure the quality and effectiveness of the purchase process. Weapon equipment purchase refers to the process of purchasing various types of weapon and supporting equipment in order to pursue the military goals. The weapon equipment purchase is an important part of the entire life cycle of equipment acquisition. It is the follow-up stage of weapon equipment pre-research and scientific research. It is a key step in linking weapon equipment purchase and performance. Weapon purchase performance refers to the relative relationship between weapon purchase and corresponding investment [1], which is, purchase of weapon and equipment at the most reasonable price, with good quality and service to meet the demand. Going through the rapid development of emerging technologies like big data, artificial intelligence, and the increasing complexity of weapon and equipment market, It is important to figure out how to reach the goals of weapon and equipment development, and maximize the quality and benefits of weapon and equipment purchase to ensure it is growing steadily. in this paper, by establishing a scientific, efficient, and operable weapon performance evaluation indicator system and model, we are expected to unravel these problems.

Weapon equipment purchase performance evaluation refers to the acquisition department using performance evaluation indicators to construct an evaluation model based on the purchase goals, and conducting a comprehensive, objective, fair and systematic evaluation. The performance evaluation is an important part of weapon equipment purchase, also a constitution of the whole process of equipment
acquisition evaluation that cannot be ignored. In recent years, the military has systematically launched a series of equipment acquisition evaluation and achieved good results. But in general, the performance evaluation of the military equipment acquisition is still in the beginning stage compared with the performance evaluation of government acquisition. It also has problems such as stereotype methods, incapable indicator system, unscientific evaluation model, and insufficient evaluators. Therefore, there is an urgent need to build a performance evaluation indicator system that adapts to the characteristics and rules of weapon equipment purchase and establish a scientific and feasible weapon equipment purchase performance evaluation model to provide theoretical and methodological references for the evaluation. This paper introduced flat weapon purchase performance evaluation indicators, established a performance evaluation model based on support vector machine, used existed data to train the model, and conducted a case analysis.

2. Weapon Equipment Purchase Performance Evaluation Indicator System

Some domestic scholars have done research on the construction of government acquisition evaluation indicator system. Xu Limin [2] (2018) built a university-government acquisition performance evaluation indicator system from the aspects of economy, efficiency, effectiveness, fairness, society and environment. Hong Wenkai [3] (2019) constructed a university-government acquisition performance evaluation system from the aspects of economic benefits, acquisition benefits, and system integrity; Zhang Xiaoli [4] (2018) constructed government acquisition performance evaluation indicators regarding the budget link, acquisition link and payment link; Yang Xuexue [5] (2020) constructed a government acquisition performance evaluation Indicator system from five aspects of input and output, economic benefits, social benefits, development and regulatory supervision; Xue Qi [6] (2017) proposed and constructed an indicator system for equipment acquisition performance evaluation in terms of evaluation objects, evaluation levels, and evaluation time limits, and analyzed the macro, meso and micro evaluation indicator systems respectively. This paper took the weapon equipment acquisition performance of a certain department as the evaluation object, and constructed an evaluation indicator system composed of 12 dimensions, including budget progress, cost-benefit ratio, expenditures reduction rate, supplier satisfaction, purchaser satisfaction, customer satisfaction, purchase cycle rationality, qualification rate, price rationality, competition, success rate, and policy completeness [1-7].

2.1. Weapon Equipment Purchase Budget Progress

The weapon equipment purchase budget progress \(x(1)\) refers to the budgetary expenditure of the weapon equipment purchase department. This indicator is a quantitative indicator, calculated as follows:

\[
x(1) = \begin{cases} \frac{x_s(1)}{x_y(1)}, & x_s(1) < x_y(1) \\ 1, & x_s(1) \geq x_y(1) \end{cases}
\]

Among them, \(x_s(1)\) is the actual expenditure of weapon and equipment purchase and \(x_y(1)\) is the budgetary expenditure of weapon equipment purchase. The value of this indicator ranges from 0 to 1. Getting higher indicator value means getting closer to the budget target.

2.2. Weapon Equipment Purchase Cost-Benefit Ratio

The weapon equipment purchase cost-benefit ratio \(x(2)\) refers to the cost of acquisition department in the purchase process of weapon equipment while saving expenditures. This indicator is a quantitative indicator, calculated as follows:

\[
x(2) = \begin{cases} \frac{x_s(2)}{x_y(2)}, & x_s(2) < x_y(2) \\ 1, & x_s(2) \geq x_y(2) \end{cases}
\]
Among them, $x_r(2)$ represents the budget expenditures for weapon and equipment purchase, $x_s(2)$ refers to the actual expenditures for weapon and equipment purchase, and $x_z(2)$ is the actual expenditures for weapon and equipment purchase including all the purchase-related expenses. The value of this indicator ranges from 0 to 1. Getting higher indicator value means getting closer to the cost-benefit ratio target.

2.3. Weapon Equipment Purchase Expenditures Reduction Rate

The weapon equipment purchase expenditures reduction rate $x(3)$ refers to the degree of expenditure-saving of the purchase. This indicator is a quantitative indicator, calculated as follows:

\[
x(3) = \begin{cases} \frac{x_r(3) - x_s(3)}{x_r(3)}, & x_r(3) > x_s(3) \\ x_s(3), & 0, x_s(3) \leq x_r(3) \end{cases}
\]

\[x(3) = \begin{cases} \frac{x_r(3) - x_s(3)}{x_r(3)}, & x_r(3) > x_s(3) \\ x_s(3), & 0, x_s(3) \leq x_r(3) \end{cases}
\]

$x_r(3)$ is the weapon and equipment for budget expenditure, $x_s(3)$ represents actual expenditure of weapon and equipment purchase. The value of this indicator ranges from 0 to 1. Getting higher indicator value means getting closer to the expenditure-saving goal.

2.4. Weapon Equipment Supplier Satisfaction

Weapon and equipment purchase suppliers satisfaction $x(4)$ means that the suppliers are satisfied with the process and effects of weapon and equipment purchase activities. This indicator is a quantitative indicator, calculated as follows:

\[
x(4) = \frac{x_m(4)}{x_{zong}(4)}
\]

Among them, $x_m(4)$ is the number of satisfied suppliers is the total number of suppliers. The value of this indicator ranges from 0 to 1. Getting higher indicator value means getting higher suppliers satisfaction.

2.5. Weapon Equipment Purchaser Satisfaction

Weapon equipment purchaser satisfaction $x(5)$ refers to the satisfaction of the acquisition department with the process and effects of weapon and equipment purchase activities. This indicator is a quantitative indicator, calculated as follows:

\[
x(5) = \frac{x_m(5)}{x_{zong}(5)}
\]

Among them, $x_m(5)$ refers to the number of satisfied purchaser, $x_{zong}(5)$ represents the total number of purchaser. The value of this indicator ranges from 0 to 1. Getting higher indicator value means getting higher purchaser satisfaction.

2.6. Weapon Equipment Customer Satisfaction
Weapon equipment customer satisfaction $x(6)$ measures how the weapon and equipment purchased meet the customer need. This indicator is a quantitative indicator, calculated as follows:

$$x(6) = \frac{x_m(6)}{x_{zong}(6)}$$  \hspace{1cm} (6)

Among them, $x_m(6)$ represents the number of satisfied customers, and $x_{zong}(6)$ is the total number of customers. The value of this indicator ranges from 0 to 1. Getting higher indicator value means getting higher customer satisfaction.

2.7. Weapon Equipment Purchase Cycle Rationality

Weapon equipment purchase cycle rationality $x(7)$ refers to the ratio of actual weapon equipment purchase time to expected weapon equipment purchase time, and this indicator is a quantitative indicator, calculated as follows:

$$x(7) = \frac{x_h(7)}{x_{zong}(7)}$$  \hspace{1cm} (7)

Among them, $x_h(7)$ is the number of purchased projects that meet the purchase cycle, $x_{zong}(7)$ represents the total number of purchase projects. The value of this indicator ranges from 0 to 1. Getting higher indicator value means getting closer the purchase cycle goal.

2.8. Weapon Equipment Purchase Qualification Rate

The qualification rate of weapon and equipment $x(8)$ represented that to which extent the quality of the weapon and equipment purchased meets the requirements. This indicator is a quantitative indicator, calculated as follows:

$$x(8) = \frac{x_h(8)}{x_{zong}(8)}$$  \hspace{1cm} (8)

Among them, $x_h(8)$ represents the number of qualified weapon and equipment purchased, $x_{zong}(8)$ is the total number of purchased weapon and equipment. The value of this indicator ranges from 0 to 1. Getting higher indicator value means getting higher qualification rate.

2.9. Weapon Equipment Purchase Price Rationality

Weapon equipment purchase price rationality $x(9)$ refers to the ratio of the actual price of weapon equipment purchase to the budget price. This indicator is a quantitative indicator, calculated as follows:

$$x(9) = \begin{cases} \frac{\sum x_s(9)}{\sum x_s(9)}, & \sum x_s(9) \leq \sum x_r(9) \\ \frac{\sum x_s(9)}{\sum x_s(9)}, & \sum x_s(9) > \sum x_r(9) \end{cases}$$  \hspace{1cm} (9)

Among them, $x_s(9)$ is the actual price of weapon and equipment, and $x_r(9)$ is the budget price of weapon and equipment. The value of this indicator ranges from 0 to 1. Getting higher indicator value means getting more reasonable purchase price.

2.10. Weapon Equipment Purchase Competition
Weapon equipment purchase competition $x(10)$ represents to which extent the purchase of weapon equipment adopts the competitive acquisition method. This indicator is a quantitative indicator, calculated as follows:

$$x(10) = \frac{x_j(10)}{x_{zong}(10)}$$

Among them, $x_j(10)$ represents the number of purchase projects that have adopted the competitive purchase method, and $x_{zong}(10)$ is the total number of purchase projects. The value of this indicator ranges from 0 to 1. Higher indicator value means higher competition degree.

2.11. Weapon Equipment Purchase Success Rate
Weapon equipment purchase success rate $x(11)$ refers to the one-time purchase during the weapon equipment purchase process. During the purchase of weapon and equipment, due to purchase schemes or purchase specifications and other causes may result in the failure of the bid, which will not only complicate the purchase process, but also lead to economic losses. This indicator is a quantitative indicator, calculated as follows:

$$x(11) = \frac{x_c(11)}{x_{zong}(11)}$$

Among them, $x_c(11)$ is the number of projects that complete the weapon equipment purchase at one time, and $x_{zong}(11)$ represents the total number of purchase projects. The value of this indicator ranges from 0 to 1. Higher indicator value means higher success rate.

2.12. Weapon Equipment Purchase Policy Completeness
Weapon equipment purchase policy completeness $x(12)$ refers to the complete process of weapon equipment purchase planning, execution, and acceptance, as well as the completeness of policies systems involving elements like methods, supervision and purchase personnel. This indicator is a qualitative indicator, with values ranging from 0 to 1. Indicator value getting higher means policy system getting more complete.

3. Weapon Equipment Purchase Performance Evaluation Model Based on Support Vector Machine
3.1. Basic principles of support vector machine method
Support Vector Machine (SVM) is a new machine learning method developed on the basis of statistical learning theory. This method has the advantages like small sample size, short training time, and low complexity. It can effectively fit the complex linear or nonlinear relationship between input and output. The essence of this method is to solve the problem of binary classification. The core is to construct the optimal hyperplane, map the input evaluation indicator score to the high-dimensional feature space through the kernel function, and then find the optimal classification hyperplane in the space. This paper will use the multi-classification method of support vector machine, and use the kernel function to fit and solve the purchase performance evaluation problem. The basic principle of support vector machine is shown in Figure 1.
Fig.1 Basic principles of support vector machine

Assuming training samples for weapon equipment purchase performance evaluation: \( \{x_i, y_i\}, \quad i = 1, 2, \cdots, k \). Among them, \( x_i \) represents the evaluation indicator value of weapon equipment purchase performance, \( y_i \) is the evaluation result level. Establish the regression model as follow:

\[
y = \langle g \cdot x \rangle + b
\]

Among them, \( g = (g_1, g_2, \cdots, g_m) \) represents the weight vector, \( b \) is the threshold. Taking training error as a constraint, the optimization can be described as:

\[
\begin{cases}
\min \phi(g) = \frac{1}{2} \|g\|^2 \\
\text{s.t.} \quad y_i - \langle g \cdot x \rangle - b \leq \epsilon \\
\langle g \cdot x \rangle + b - y_i \leq \epsilon \\
\quad i = 1, 2, \cdots, k
\end{cases}
\]

In the objective function, linear regression can be achieved by using an appropriate inner product function \( L(x_i, x_j) \), the relaxation variable introduced and convert the objective function into:

\[
\begin{cases}
\max \left\{ T = \frac{1}{2} \sum_{i=1}^{k} \sum_{j=1}^{k} (a_i - \alpha_i^*)(a_j - \alpha_j^*) \times L(x_i, x_j) - \epsilon \sum_{i=1}^{k} (a_j + \alpha_j^*) + \sum_{i=1}^{k} y_i (a_i - \alpha_i^*) \right\} \\
\text{s.t.} \quad \sum_{i=1}^{k} (a_i - \alpha_i^*) = 0 \\
\quad 0 \leq a_i \leq C, 0 \leq \alpha_i^* \leq C
\end{cases}
\]

Among them, \( a_i, \alpha_i^* \) are the Lagrangian multiplier, \( C \) is the penalty coefficient, and the larger the value, the greater the penalty for exceeding the data points of \( \epsilon \). According to the sufficient conditions for optimization, the decision function can be obtained:

\[
f(X) = \sum_{x_i \in \mathcal{H}} (a_i - \alpha_i^*) L(x_i, x_j) + b
\]
Among them, \( s_v \) is Support Vector Set (SV). When \( f(X) > 0 \), \( y = 1 \), when \( f(X) < 0 \), \( y = -1 \), which means, the symbol of \( f(X) \) determines the classification result.

The classic support vector machine can only deal with the two classification problems. In order to evaluate the weapon equipment acquisition performance evaluation three-level results (excellent, qualified, unqualified), this paper will construct three support vector machine sub-classifiers. At present, the multi-classification methods based on support vector machines mainly include: One-Against-One SVM (OAO-SVM), One-Against-All SVM (OAA-SVM), Decision Directed Acyclic Graph SVM (DDAG-SVM), etc. Hou Xiaoli et al. [8] (2016) analyzed the One-Against-One, One-Against-All, decision binary tree algorithm, directed acyclic graph and other algorithms of support vector machine, and compared the performance. Zhai Jia et al. [9] (2015) proposed two new K (K>3) multi-classification algorithms. Xie Rongyan et al. [10] (2018) analyzed the influencing factors of production equipment acquisition demand in light of the small sample data of enterprise production equipment acquisition, and constructed a prediction model of acquisition demand based on support vector machines. Niu Ben et al [11] (2015) proposed a directed acyclic graph-dual support vector machine multi-classification method for the inefficient problem and sample imbalance problem in the multi-class support vector machine algorithm. Li Kun et al. [12] (2018) designed a cost-sensitive support vector machine classifier based on different misclassification costs of suppliers, optimized the parameters of the classifier using particle swarm optimization, and used probabilistic output methods for the results of multi-class classifiers. Song Zhaqing [13] (2015) analyzed two methods such as the “decomposition-recombination” method and the “direct solution” method of support vector machines, and pointed out the advantages and disadvantages and the direction of future improvement.

In this paper, the OAO-SVM method of support vector machine is used to construct three support vector machine sub-classifiers. Finally determined the level of the evaluation object by voting.

3.2. Evaluation Steps of Weapon Equipment Purchase Performance Based on Support Vector Machine

The performance evaluation steps of weapon equipment purchase performance based on support vector machines are shown in Figure 2. (1) Construct a sample set. According to the weapon equipment purchase performance evaluation indicator score and evaluation result, the training sample set is created. (2) Construct a support vector machine model. According to the evaluation results, the sample is divided into 3 categories to form 3 sub-classifiers of support vector machine (excellent/qualified, excellent/unqualified, qualified/unqualified) and train them separately to get the support vector machine model. (3) Carry out evaluation. For a certain department's weapon equipment purchase performance indicator, input the trained support vector machine model to get the frequency of different evaluation levels (excellent, qualified, and unqualified). According to the voting algorithm, we can determine the evaluation level of each acquisition department.

![Fig. 2 Evaluation Steps of Weapon Equipment Purchase Performance Based on Support Vector Machine](image-url)
4. Case Analysis

Using the weapon purchase performance evaluation cases of previous years as sample data (the data is fuzzified), the evaluation of weapon purchase performance of certain departments this year was carried out. The sample set of weapon equipment purchase performance evaluation is shown in Table 1 (part).

Table 1 Sample set of weapon equipment purchase performance evaluation (part)

| Acquisition Department | Budget | Progress | Cost-Benefit Ratio | Expenditures Reduction Rate | Supplier Satisfaction | Purchaser Satisfaction | Customer Satisfaction | Purchase Cycle Rationality | Qualification Rate | Price Rationality | Competition Success Rate | Policy Completeness | Evaluation Results |
|-------------------------|--------|----------|-------------------|----------------------------|-----------------------|-----------------------|-------------------------|----------------------|-------------------|----------------------|----------------------|------------------|------------------|
| 1                       | 0.8    | 0.7      | 0.75              | 0.85                       | 0.9                   | 0.76                  | 0.7                     | 0.76                 | 0.9               | 0.78                 | 0.55                 | Excellent         |
| 2                       | 0.75   | 0.8      | 0.92              | 0.76                       | 0.9                   | 0.76                  | 0.9                     | 0.9                  | 0.78              | 0.65                 | 0.9                 | Excellent         |
| 3                       | 0.86   | 0.85     | 0.86              | 0.9                        | 0.72                  | 0.86                  | 0.9                     | 0.85                 | 0.8               | 0.95                 | 0.9                 | Excellent         |
| 4                       | 0.58   | 0.7      | 0.65              | 0.8                        | 0.65                  | 0.6                    | 0.8                     | 0.5                  | 0.65              | 0.6                 | 0.9                 | Qualified         |
| 5                       | 0.5    | 0.7      | 0.8               | 0.65                       | 0.6                  | 0.6                    | 0.8                     | 0.5                  | 0.65              | 0.6                 | 0.9                 | Qualified         |

Using the built support vector machine model, calculate the evaluation conclusions of the performance evaluation of 4 departments of weapon equipment purchase, as shown in Table 2.

Table 2 Evaluation Conclusion of Weapon Equipment Purchase Performance

| Acquisition Department | Budget | Progress | Cost-Benefit Ratio | Expenditures Reduction Rate | Supplier Satisfaction | Purchaser Satisfaction | Customer Satisfaction | Purchase Cycle Rationality | Qualification Rate | Price Rationality | Competition Success Rate | Results Frequency | Evaluation Results |
|-------------------------|--------|----------|-------------------|----------------------------|-----------------------|-----------------------|-------------------------|----------------------|-------------------|----------------------|----------------------|------------------|------------------|
| A                       | 0.8    | 0.7      | 0.75              | 0.85                       | 0.9                   | 0.76                  | 0.7                     | 0.76                 | 0.9               | 0.72                 | 0.9                 | Excellent/2, Excellent/1 |
| B                       | 0.75   | 0.8      | 0.92              | 0.76                       | 0.85                  | 0.9                   | 0.76                   | 0.9                  | 0.78              | 0.65                 | 0.8                 | Excellent/2, Excellent/1 |
| C                       | 0.86   | 0.85     | 0.86              | 0.9                        | 0.72                  | 0.86                  | 0.99                   | 0.8                  | 0.8              | 0.95                 | 0.9                 | Excellent/1, Qualified/2 |
| D                       | 0.58   | 0.7      | 0.65              | 0.75                       | 0.62                  | 0.65                  | 0.72                   | 0.72                 | 0.72              | 0.56                 | 0.75                | Qualified/2, Qualified/1 |

It can be seen from Table 2 that acquisition department A and B performance evaluation results show “Excellent”, and C and D evaluation results show “Qualified”.

5. Conclusion

Weapon equipment purchase performance evaluation is an vital step of acquisition management and decision-making, quality indication for the scientific development of weapon equipment purchase. In this paper, we established a set of scientific and practical weapon equipment purchase performance evaluation indicators and methods in order to improve the performance evaluation, used the support vector machine model to establish weapon equipment purchase performance evaluation indicators and models. In the next step, we will establish an adaptive weapon equipment purchase evaluation indicator system according to different fields and different types of weapon equipment purchase activities, and collect a wider range of data to train the support vector machine model, optimize the parameters and algorithms, and improve weapon equipment purchase to a more scientific level.

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