Evaluation of artillery equipment maintenance support capability based on grey clustering

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Abstract. This paper, the theory and method of evaluating the capability of equipment maintenance support in China and abroad are studied, from the point of view of the combat task of artillery troops and the strategic attachment in the future military struggle. This paper establishes the framework of the evaluation Index system of the equipment maintenance support capability of the artillery units, and applies the grey clustering method to the evaluation of the equipment maintenance support capability of the artillery units, and finally evaluates the equipment maintenance and support capability of the artillery brigade as an example, and analyzes the evaluation results. This paper finds out the outstanding problems existing in the maintenance and support of military equipment, and puts forward some constructive suggestions, in order to improve the status of military equipment maintenance and support and improve the level of future equipment maintenance.

1. Introduction

With the improvement of the artillery maneuver capability, the expansion of the battle radius, the increase of the artillery and missile range, especially the rapid development and application of the precision guidance weapon, the large area killing weapon, the new type ammunition and the fire control system, the position and function of long-range firepower war are more and more prominent. So, in preparation for the military struggle, to improve the ability of the maintenance and support of the artillery units, to ensure the continuity of combat effectiveness is an important task. However, how to evaluate the capability of the existing military equipment maintenance and support, put forward reasonable suggestions on the capability of military equipment maintenance and support, and provide the correct development direction for the development of the troops is the most important problem.

At present, the commonly used state assessment methods include: Expert scoring method, Delphi method, fuzzy comprehensive evaluation, grey clustering, neural network and so on. The expert scoring method and Delphi method have a strong subjectivity, which greatly reduces the accuracy and reliability of the evaluation results. The fuzzy comprehensive evaluation emphasizes the ambiguity of the factors affecting things, overcomes the drawbacks of the "unique solution" in the traditional mathematics method, and the intelligent artificial evaluation method, such as neural network, has the ability of self-learning and self-adaptive, but it needs a lot of training samples and the calculation process is too complicated. The object of the grey clustering theory is the "small sample" uncertain system of "partial information unknown", no strict requirements on the samples, artillery Brigade equipment maintenance support by the geographical environment, traffic level and other factors, the overall grasp of all the information has some difficulties, so the evaluation method of grey clustering in the artillery Brigade equipment maintenance support capability evaluation is more applicable.
2. Evaluation Index System construction

The establishment of the index System of artillery Brigade maintenance support capability is the basis of carrying out scientific evaluation activities, and also the necessary link of carrying out evaluation activities. The Delphi method is widely consulted, exchanging information repeatedly, combining the actual situation of artillery brigade, and setting up the evaluation Index system as shown in Fig. 1.

![Index system of Artillery Brigade equipment maintenance support capability](image_url)

**Figure 1** Index system of Artillery Brigade equipment maintenance support capability

3. Principle of Grey clustering evaluation

Gray evaluation is based on the gray system theory, the system belongs to the factor in a certain period of time in the state, make a semi-quantitative semi-quantitative evaluation and description, in order to the comprehensive effect and overall level of the system to form a comparable concept and category. Grey evaluation method can be divided into two different types: grey statistical evaluation and grey clustering evaluation. Among them, the grey clustering evaluation is to generalize the whitening weight function of the clustering object to different kinds of indexes, and to determine which grey class the clustering object belongs to. There are \( n \) clustering objects, \( m \) clustering indexes and \( s \) different grey categories. According to the \( i (i = 1,2,\ldots,n) \) object, the sample value \( X_i \) of indicator \( j (j = 1,2,\ldots,m) \), and \( j \) objects are classified into \( k (k = 1,2,\ldots,s) \) grey categories, the concrete steps are as follows.

3.1. Establish a status comment set

According to the evaluation requirements of the Artillery Brigade equipment maintenance support capability indicators to divide the value range into 5 gray classes, this article set, the grade of gray class is divided into \( e = 1,2,3,4,5 \), representing very good, good, general, poor, very poor, five states.

3.2. Structure Whitening Weight function

The traditional grey clustering evaluation mostly uses four kinds of whitening weight function: The grey K-whitening weight function of Set index \( f_i^j (\bullet) \equiv x_i^j (1), x_i^j (2), x_i^j (3), x_i^j (4) \) are the turning points, and the typical whitening weight function is recorded as \( f_i^j \left[ x_i^j (1), x_i^j (2), x_i^j (3), x_i^j (4) \right] \), the piecewise expressions is shown in the formula (1);the upper limit measure whitening weight function is recorded as \( f_i^j \left[ x_i^j (1), x_i^j (2), x_i^j (3), x_i^j (4) \right] \); The right function of whitening weight is recorded as \( f_i^j \left[ x_i^j (1), x_i^j (2), x_i^j (3), x_i^j (4) \right] \); The lower limit measure whitening weight function is recorded as \( f_i^j \left[ x_i^j (1), x_i^j (2), x_i^j (3), x_i^j (4) \right] \). The appropriate grey whitening weight function is constructed according to the known information.
3.3. Evaluation Index Weight DETERMINATION

Analytic hierarchy Process (analytic hierarchy procedure, AHP), which was first proposed in the early 1970s by the famous American research operations, T. L. Saaty, which is a multi-objective decision analysis method combining quantitative analysis and qualitative analysis. Specifically, the analytic hierarchy process is to decompose a complex and huge problem into various factors, and then the factors of the decomposition are grouped by affiliation and constructed into an orderly hierarchical hierarchy. By the decision-makers on the importance of the factors in the hierarchy according to a certain percentage of the scale of the two comparison and judgment, in order to determine the level of each factor relative to the relative importance of the previous factor (ie, the weight value). Finally, the weights are synthesized in the hierarchical structure to obtain the weighted values of the lowest layer relative to the highest level.

3.4. Calculation of comprehensive clustering coefficients

Computational object \( i(i = 1, 2, \ldots, n) \) on the comprehensive clustering coefficients \( \sigma_i^k \) of grey class \( k(k = 1, 2, \ldots, s) \).

\[
\sigma_i^k = \sum_{j=1}^{s} f_j(x_i) \times w_j \quad (2)
\]

Select \( \max_{i=1,\ldots,s} \{\sigma_i^k\} = \sigma_i^{k^*} \) as the final result of the state evaluation, and judge the cluster object belongs to the grey class \( k^* \).

4. Case Studies

This paper evaluates and compares the equipment maintenance and support capability of some two artillery brigades (A Brigade and B Brigade) in frontier areas, takes the same personnel, vehicle and maintenance support tasks, and evaluates the actual values of each performance evaluation index as shown in table 1.

**Table 1** measurement values for each index

| Evaluation objectives | Evaluation indicators | Standard value | A Brigade measured value | B Brigade measured value |
|-----------------------|-----------------------|----------------|--------------------------|-------------------------|
| Compatibility         | Number of dedicated maintenance equipment | 4              | 3                        | 2                       |
| Maintainability       | Average repair time   | 5 hours        | 6 hours                  | 6.5 hours               |
| Testability           | Equipment failure Detection Rate | 15%            | 21%                      | 18%                     |
| Usability             | Equipment intact Rate | 90%            | 86%                      | 87%                     |
| Preparation structure | Percentage of professional technicians | 80%            | 73%                      | 70%                     |
| Educational level     | Level eligibility Percentage | 60%            | 77%                      | 79%                     |
| Training level        | Training time         | 20 h/week      | 16 h/week                | 16 h/week               |
| Economic              | Transportation and Packing fee | 1 million      | 1.43 million             | 1.67 million            |
| Financial Benefits    | Rate of balance of appropriations | 10 million     | 9.83 million             | 9.35 million            |
| Maintenance Spare Parts| Spare Parts Inventory Rate | 95%            | 82%                      | 85%                     |
| Mobility capability   | Rate of passing per unit time | 90%            | 84%                      | 80%                     |
The remaining indexes are qualitative indexes, according to empirical statistical analysis or subjective judgment to determine the corresponding gray class. By the second section it is known that \( S = \{S_1, S_2, S_3, S_4, S_5\} = \{\text{is good, good, general, poor, very bad}\} \) five gray classes, The corresponding whitening weight functions are 

\[
\begin{align*}
    f_1^1 &= [80, 90, -, -], \quad f_2^1 = [70, 80, -90], \quad f_3^1 = [60, 70, 80, 90], \quad f_4^1 = [60, 70, -80], \\
    f_5^1 &= [-80, -60, 70], \quad f_2^2 = [12, 30, -30], \quad f_3^2 = [8, 12, -30], \quad f_4^2 = [1, 8, 10, 30], \quad f_5^2 = [-1, 8, -1, 8].
\end{align*}
\]

The weights are determined by AHP, the judgment matrix is obtained, and the corresponding weight value is calculated. The weight vector of the indicator layer relative to the target layer is 

\[ \mathbf{w} = \{0.234, 0.250, 0.176, 0.078, 0.157, 0.105\} \], and \( \lambda_{\max} = 6.128 \), \( CI = 0.032 \), \( CR = 0.036 < 0.1 \), through consistency verification. Similarly, we can get the weight vector of the decision-making level relative to the index layer and the grey clustering coefficient matrix, then the grey class of each index is judged, and the final evaluation result is shown in Table 2.

**Table 2 Evaluation results of maintenance support capability**

| Evaluation Object | Weight | A Brigade evaluation results (grey class) | B Brigade evaluation results (grey class) |
|-------------------|--------|------------------------------------------|------------------------------------------|
| \( B_1 \)        |        | C_1 \quad 0.225 | Second | First |
| \( B_1 \)        |        | C_2 \quad 0.025 | Second | Second |
| \( B_1 \)        |        | C_3 \quad 0.395 | Third | Third |
| \( B_1 \)        |        | C_4 \quad 0.355 | Second | Second |
| \( B_1 \)        |        | C_5 \quad 0.375 | Second | Second |
| \( B_1 \)        |        | C_6 \quad 0.5 | Third | Second |
| \( B_1 \)        |        | C_7 \quad 0.25 | Third | Second |
| \( B_2 \)        |        | C_8 \quad 0.125 | First | First |
| \( B_2 \)        |        | C_9 \quad 0.75 | Third | Third |
| \( A \)          |        | C_{10} \quad 0.625 | Third | Third |
| \( A \)          |        | C_{11} \quad 0.375 | Third | Third |
| \( A \)          |        | C_{12} \quad 0.077 | Third | Third |
| \( A \)          |        | C_{13} \quad 0.69 | Third | Third |
| \( A \)          |        | C_{14} \quad 0.233 | Third | Third |
| \( A \)          |        | C_{15} \quad 0.875 | Third | Third |
| \( A \)          |        | C_{16} \quad 0.125 | Third | Third |

From table 3 We can judge a brigade equipment maintenance support ability comprehensive ash class coefficient belongs to the third Ash class, namely belongs to General; B Brigade Equipment Maintenance support ability comprehensive ash class coefficient belongs to the second Ash class, namely belongs to better. Through the data analysis, we can know that the equipment quality, B brigade in equipment matching equipment quantity, fault missing rate, intact, and other aspects are more prominent; human resources, a brigade there are cadres, soldiers vacancy situation, and the level of education is low, restricting the training of technical personnel; in the environment and climate, b Brigade is located in the lower altitude area, comparatively speaking, the training environment is superior; maintenance economy, a brigade is limited by the environment, traffic is not very convenient, so the transport packaging costs are higher, At the same time, compared to the B travel costs are relatively single, so the balance is also more; Maintenance management, a brigade information security, information sharing, more investment; spare parts security and mobile protection, two brigades have a lack of perishable materials, the supply of nonvolatile materials sufficient situation, overall, B brigade situation better. The results of the collected samples and the results were compared to the actual state of the evaluation.

**5. Summary**

This paper takes two artillery Brigade maintenance support ability as an example to carry on the grey cluster appraisal, and compares the analysis conclusion, finds out the existing problems in the maintenance and support construction of the artillery Brigade, and puts forward the following suggestions:
(1) Clear direction of development. The establishment of equipment maintenance guarantee is a powerful guarantee to ensure the smooth completion of the troops’ execution, and to meet the needs of the future war.

(2) Pay attention to talent training. To pay attention to talents, to make the best of their abilities, to avoid the loss of professional and technical talents, to improve their education, to a certain extent, to characterize the learning ability, which can greatly shorten the training time of professional talents.

(3) Increase material input. Perfect maintenance equipment Facilities construction, reasonable configuration maintenance equipment and management resources, maintain the good technical status and management order of maintenance equipment, adapt to the new situation under the requirements of the maintenance and protection of weapons and equipment.

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