Analysis on Evaluation Method for Support Equipment System Effectiveness

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Abstract: In order to study the applicability of evaluation method in the process of service support equipment effectiveness evaluation, this paper selects several kinds of evaluation method which are widely used in the field of equipment effectiveness evaluation, summarizes their basic ideas and general steps, analyzes the application of each evaluation method in the process of service support equipment effectiveness evaluation, and provides a theoretical reference for the practical application of logistics support equipment system effectiveness evaluation method.

1. Introduction
Support is the guarantee and service activities which is organized and implemented by the equipment user for carrying out tasks and meeting other needs; support equipment is the equipment used by the equipment user to carry out engineering support, combat support or technical support. According to the new situation, with the deepening of the construction of the equipment maintenance and support system, the status and function of support equipment have been further consolidated and strengthened [1].

Effectiveness evaluation runs through the whole process of equipment demonstration, development, production, use, maintenance and decommissioning [2]. It is one of the necessary means to improve the capability and search for the defects of equipment system. At present, the domestic and foreign research on the effectiveness evaluation of support equipment is relatively few. At the same time, the research direction, index system and mathematical model of equipment effectiveness evaluation are different from other types of equipment, and support equipment have their own characteristics. According to the function, task and use characteristic of support equipment, this paper studies the application of the effectiveness evaluation method in each stage of the support equipment system effectiveness evaluation, in order to provide the theory support for the research of the support equipment effectiveness evaluation.

2. Overview of the effectiveness evaluation of support equipment
2.1 Definition of equipment effectiveness
Effectiveness generally refers to the ability of a system to achieve a specified use goal under specified conditions [3]. Equipment effectiveness can be understood as the ability of a certain type of equipment to complete a specified task under certain conditions, and its numerical value can express as probability or other physical quantities.

Equipment effectiveness can usually be divided into single effectiveness, system effectiveness and dynamic effectiveness [4]. The single effectiveness refers to the ability of the equipment to complete a single task under certain conditions, and the system effectiveness is the comprehensive evaluation of the equipment effectiveness, which refers to the ability of the equipment to complete a set of specific tasks under ideal...
conditions. Dynamic effectiveness refers to the ability of equipment to complete specified tasks under specific environment. Usually, dynamic effectiveness is less than system effectiveness. This paper mainly analyzes and studies the effectiveness evaluation of the support equipment system.

2.2 Characteristics of the effectiveness evaluation of support equipment
Because of the special characteristics of practical tasks, background and functional division, support equipment has distinct characteristics in each stage of system effectiveness evaluation [7-9]:

1. The mission profile of the support equipment
   The effectiveness of support equipment is not only related to its own performance parameters, but also needs to consider the influencing factors of the equipment of the support department.

2. The effectiveness index of the support equipment
   The main tasks of support equipment are engineer support and technical support, which does not directly impact on target, so the selection of its effectiveness index is more focused on the Guaranteed performance, such as communication support, power supply support and so on.

3. The evaluation method of support equipment
   The characteristics of support equipment make the applied scope and stage of evaluation method in the process of effectiveness evaluation have its particularity.

3. Overview and classification of equipment effectiveness evaluation method
Effectiveness evaluation method are the theoretical basis and guidance of equipment effectiveness evaluation, which runs through the whole process of effectiveness evaluation. According to different criteria, the effectiveness evaluation method can be classified according to the mathematical method used in the evaluation, or can be distinguished according to the nature of the evaluation method [8,9].

3.1 Classification by mathematical method
According to the mathematical methods which were adopted, the evaluation method can be divided into statistical method, analytical method and simulation method.

   1) The statistical method refers to the calculation of the performance index of the data such as exercise, test and actual combat over the years;
   2) The analytical method is to establish the analytical function between the constraint condition and the effectiveness index to calculate the evaluation result;
   3) The simulation method is carried out under certain constraints to evaluate the equipment effectiveness.

3.2 Classification by nature of evaluation method
According to the nature of the evaluation method, the method can be divided into subjective evaluation method, objective evaluation method and subjective-objective evaluation method. Based on the nature of the evaluation method, this paper discusses the applicability of the relevant method in the process of effectiveness evaluation.

1. Subjective evaluation method
   Subjective evaluation method is to evaluate the effectiveness of the system according to the subjective judgment of experts, including intuition method, expert investigation method, Delphi method and analytic hierarchy process (AHP). Intuitive method and expert investigation method are directly graded by experts, the subjective arbitrariness is the greatest. Delphi method eliminates the shortcomings of group decision-making and enhances the scientific nature of evaluation results through anonymous feedback mechanism. AHP hierarchies the complex system according to the membership relationship of the influencing factors.

2. Objective evaluation method
   Objective evaluation method is to reduce or eliminate the interference of subjective factors in the evaluation process through data analysis and model construction. Objective evaluation method includes technique for order preference by similarity to ideal solution (TOPSIS), principal component analysis
(PCA) and factor analysis method. TOPSIS [6] can realize the evaluation of the equipment system effectiveness by comparing the Euclidean distance between the pre-evaluation scheme and the optimal scheme and the worst scheme, which is suitable for simple systems with less indexes. PCA [10] reduces the difficulty and complexity of the problem by orthogonal transformation, but depends on the source data. Factor analysis is similar to principal component analysis, here do not repeat.

3. subjective-objective evaluation method

The combination of subjective and objective evaluation combines the advantages of subjective evaluation and objective evaluation, the objectivity and accuracy of the evaluation results are improved with less reliance on statistics and raw materials. Fuzzy comprehensive evaluation (FCE), ADC, grey whitening weight function clustering method and neural network method are the main evaluation method. FCE [8] realizes the quantitative calculation of qualitative index according to the membership degree theory of fuzzy mathematics, a better solution to the fuzzy and uncertain of judgment, but its calculation involves too many subjective factors, the evaluation results are not scientific and accurate enough. The ADC determines the internal coupling relationship by analyzing the availability vector A, the reliability matrix D and the intrinsic capacity vector of the system C. It emphasize the integrity of the findings, however, it can not accurately reflect the connection and influence between the elements of the system. The gray whitening weight function clustering method describes the membership degree of the clustering object to each gray level effectiveness evaluation for complex large systems; The neural network [9] has strong adaptive ability to assess the effectiveness of the equipment system, but it needs a lot of data support, and its accuracy also needs to be improved.

4 Applicability of the evaluation method in support equipment effectiveness evaluation

4.1 Basic processes for evaluating the support equipment effectiveness

Equipment effectiveness evaluation can usually be divided into three stages: determining the evaluation target, constructing the evaluation index system, and calculating the comprehensive evaluation value of effectiveness [9]. It contains five steps and six items, as shown in figure 1.

![Diagram](image_url)  
Figure 1. Support equipment system effectiveness evaluation steps
4.2 Application of evaluation method at all stages of support equipment effectiveness evaluation

4.2.1 Construction of Evaluation Index System Stage

The establishment of evaluation index system is the basic link of effectiveness evaluation, which mainly includes three aspects: constructing evaluation index system of support equipment system, determining evaluation index measurement model and calculating effectiveness index weight. Different from the other types equipment, the evaluation of support equipment is mainly aimed at its support effectiveness, survival effectiveness and so on. There are some problems that the relevant raw data and data are difficult to obtain directly, the influence factors of effectiveness are too complex, and there are a lot of subjective qualitative indicators in the evaluation process. According to the characteristics of each evaluation method, Delphi method, AHP method and PCA method have good applicability in this stage.

1. The application analysis of Delphi method

The system of influencing factors of support equipment effectiveness is complicated, involving a wide range and difficult to identify. Therefore, according to the above characteristics, based on Delphi method, according to the characteristics of the evaluation object, constraints and task outline, through the scoring and feedback mechanism of experts in the field of support equipment, the appropriate effectiveness evaluation index or the weight of each index can be selected. As shown in Table 1. By distributing the list of support equipment effectiveness indicators to the experts in related fields for consultation and scoring, the selection of support equipment effectiveness indicators is completed relatively scientifically and effectively.

| Table 1. Advisory list of support equipment generic effectiveness indicators |
|---------------------------------------------------|---------------------------------------------------|---------------------------------------------------|---------------------------------------------------|
| Level I indicators                              | Level I indicator code                          | Level II indicators                               | Level II indicators code                          |
| Reliability                                      | R                                                 | Mean time between failure (MTBF)                  | R₁                                                 |
| Maintenance                                      | MA                                                | Mean time to repair (MTTR)                        | MA₁                                               |
| Guaranty ability                                 | G                                                 | Number of persons guaranteed                      | G₁                                                 |
| Inherent capacity                                | I                                                 | Top speed                                        | MO₁                                               |
| Mobility                                         | MO                                                | Maximum climbing gradient                         | MO₂                                               |
| Adaptability                                     | A                                                 | Temperature adaptability                          | A₁                                                 |
| Survivability                                    | S                                                 | Infrared concealment                              | S₁                                                 |
| Human factors                                    | H                                                 | Level of education                                | H₁                                                 |

The author selects the emergency rescue scenario and trauma emergency health equipment based on Delphi method in literature [12] and [13], and verifies the feasibility of this method in constructing the evaluation index system of the effectiveness of the support equipment system.
2. The application analysis of AHP

The complexity of the performance index system of the equipment system determines that it is impossible to describe the equipment system according to a few simple sample data. In order to decompose the complex unstructured problem of the support equipment system into several parts or elements and realize the hierarchical relationship between the levels, the system can be divided into target layer, criterion layer and index layer based on AHP, so as to realize the construction of the general effectiveness evaluation index system of the support equipment.

The AHP can be combined with Delphi method in practical application, for example, in literature [14] and [15], the author establishes the evaluation index system of equipment system by AHP, according to the scale table of 1-9. The weight of each index is calculated by Delphi method.

3. The application analysis of PCA

The effectiveness index of the support equipment system usually has strong fuzziness and relevance. Through the principal component analysis method, the original multiple variables can be integrated into less orthogonal variables, so as to simplify the data structure. The contribution rate of equipment effectiveness is calculated. Take the survival effectiveness evaluation of the support equipment system as an example. Factors influencing survival effectiveness include concealment camouflage, mobile protection and recovery of equipment and several secondary index [16]. The number of times the equipment is destroyed by various factors can be counted by collecting the data of previous exercises or through combat simulation, as shown in Table 2. Based on the tabular data, the survivability correlation factor matrix of the support equipment is constructed R, the contribution rate of the principal component and the rotating load matrix of the principal component factor are calculated, and the main influencing factors related to the survivability of the support equipment are extracted.

| Table 2. Statistical table of the factors affecting the survival of the equipment |
|-----------------------------------------------|
| **Influencing factors** | **Number of equipment destroyed** |
| **Level I indicators** | **Level II indicators** | **First simulation** | **Second simulation** | **Third simulation** | ...... | **The n simulation** |
| Camouflage factors | Size $R_1$ | $R_{11}$ | $R_{12}$ | $R_{13}$ | $R_{1n}$ |
| | Geometric characteristics $R_2$ | $R_{21}$ | $R_{22}$ | $R_{23}$ | $R_{2n}$ |
| | Spectral characteristics $R_3$ | $R_{31}$ | $R_{32}$ | $R_{33}$ | $R_{3n}$ |
| | Infrared characteristics $R_4$ | $R_{41}$ | $R_{42}$ | $R_{43}$ | ...... | $R_{4n}$ |
| | Radar characteristics $R_5$ | $R_{51}$ | $R_{52}$ | $R_{53}$ | $R_{5n}$ |
| | Impairment capacity $R_6$ | $R_{61}$ | $R_{62}$ | $R_{63}$ | $R_{6n}$ |
| Mobility factors | Top speed $R_7$ | $R_{71}$ | $R_{72}$ | $R_{73}$ | $R_{7n}$ |
| | Maximum distance $R_8$ | $R_{81}$ | $R_{82}$ | $R_{83}$ | $R_{8n}$ |
| | Highway performance $R_9$ | $R_{91}$ | $R_{92}$ | $R_{93}$ | ...... | $R_{9n}$ |
| | Off-road performance $R_{10}$ | $R_{101}$ | $R_{102}$ | $R_{103}$ | $R_{10n}$ |
| Protective factors | Early warning time $R_{11}$ | $R_{111}$ | $R_{112}$ | $R_{113}$ | ...... | $R_{11n}$ |
| | Defense capability $R_{12}$ | $R_{121}$ | $R_{122}$ | $R_{123}$ | ...... | $R_{12n}$ |
| Recovery factors | Maintenance level $R_{13}$ | $R_{131}$ | $R_{132}$ | $R_{133}$ | ...... | $R_{13n}$ |
| | Spare parts support $R_{14}$ | $R_{141}$ | $R_{142}$ | $R_{143}$ | $R_{14n}$ |

Note: the $R_{mn}$ is the number of times the equipment is destroyed, the $m$ is the number of influence factors, and the $n$ is the number of simulations.

4.2.2 Evaluation model and algorithm phase

The evaluation model and algorithm mainly select the effectiveness evaluation model and algorithm of the support equipment system, and complete the aggregation and calculation analysis of the evaluation
index parameters. ADC method has a wide range of applicability and expansibility in the evaluation of weapon system effectiveness. TOPSIS has clear mathematical significance, simple calculation process and comprehensive characteristics of each evaluation method. ADC and TOPSIS have good applicability in this stage.

1. Application Analysis of TOPSIS

One of the purposes of effectiveness evaluation is to compare the advantages and disadvantages of each equipment scheme. The positive and negative ideal points can reflect the relationship and difference between the schemes by mathematical method, the method is simple, the meaning is clear, and it can be applied to the multi-scheme evaluation of the support equipment.

Set up a type of support equipment being developed, There are \( n \) assessment programs and \( m \) indicators, \( R=\{X_1, X_2, \ldots, X_n\} \), \( F=\{f_1, f_2, \ldots, f_m\} \), \( a_{ij} \) represent the index parameters of the scheme \( X_i \) on the index \( f_j \). Construct the decision matrix of this type of support equipment system \( A \) and carry on the standardization processing, Get the standardized matrix:

\[
R = (r_{ij})_{mn}
\]

\[ r_{ij} = a_{ij} / \sqrt{\sum_{i=1}^{n} a_{ij}^2}, \quad i \in N, \quad j \in M \]

In the formula (1),

Combining the weight of the \( j \) attribute of this type of support equipment with the standardized matrix, the matrix can be obtained:

\[
R_\omega = (v_{ij})_{mn}
\]

In the formula (2),

\[ v_{ij} = \omega_j \times r_{ij} \]

Synthesizing each scheme, selecting positive ideal solution \( X^+ \) and negative ideal solution \( X^- \) calculating the Euclidean distance from each pre-evaluation scheme to the ideal solution, respectively:

\[
S^+_i = \sqrt{\sum_{j=1}^{m} (v_{ij} - v^+_{ij})^2}
\]

\[
S^-_i = \sqrt{\sum_{j=1}^{m} (v_{ij} - v^-_{ij})^2}
\]

The relative closeness index of the pre-evaluation scheme to the ideal solution is calculated as follows:

\[
C_i = \frac{S^-_i}{S^+_i + S^-_i}, \quad C_i \in [0,1]
\]

The \( C_i \) can be ranked as the final evaluation results of each scheme. The closer the \( C_i \) is to 1, the closer the prediction scheme is to the ideal scheme.

In the literature [10], the author compares the Euclidean distance between different equipment performance parameters and ideal equipment to achieve the purpose of selecting the optimal scheme Based on TOPSIS. The feasibility of this method in the evaluation algorithm of equipment system effectiveness is verified.

2. The Application analysis of ADC Method

ADC methods are widely used in the field of effectiveness evaluation [18-20]. The system effectiveness evaluation of support equipment is not only limited to, but also closely related to the operational environment, weapon operators and other factors. ADC method provides an extensible basic evaluation framework for equipment system, which is suitable for the effectiveness evaluation of support equipment system under the background of multiple influencing factors.
The author studies the influence of personnel reliability on the effectiveness of equipment system by using ADC method in literature [21], and verifies the practical significance and feasibility of ADC method in the field of equipment system effectiveness evaluation.

5. Summary
Because the evaluation subject is different and the characteristics are different, the evaluation stage is different. Synthesizing the above, the characteristics of each evaluation method and its applicability in the process of equipment evaluation are listed. As shown in Table 3.

| Evaluation method | Advantages                                                                 | Disadvantages                                                                 | Applicability                                                                 |
|-------------------|-----------------------------------------------------------------------------|-------------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| Delphi            | The anonymous polling feedback mechanism eliminates the shortcomings of group decision making and enhances the scientific nature of the method. | Subjectivity is strong, too dependent on the professional evaluation experts. | The selection of evaluation index and the analysis and calculation of index weight of support equipment system. |
| AHP               | Strong theory, good hierarchy, concise form.                                | Subjective and only static effectiveness evaluation.                         | The construction of equipment effectiveness evaluation index system and the analysis and calculation of index weight. |
| PCA               | Eliminate the influence of subjective factors, of subjective factors.       | The scope of application is small, mainly used for equipment effectiveness evaluation which can be obtained by basic data. | Support equipment evaluation index streamlining synthesis and contribution rate calculation. |
| TOPSIS            | The theory is strong, the mathematics significance is obvious, the form is concise. | The scope of application is small, mainly used for the effectiveness evaluation of simple systems. | Comprehensive calculation of the effectiveness of the support equipment system. |
| FCE               | Standardized treatment of qualitative index quantification, scientific.     | The influence of subjective factors on the evaluation results can not be completely eliminated. | To ensure the quantification of qualitative indicators of support equipment. |
| ADC               | The form is concise and easy to expand, and the reliability of the system is fully considered. | It is difficult to calculate the inherent ability vector, and the state matrix is huge and difficult to deal with when calculating complex systems. | Comprehensive calculation of the effectiveness of the support equipment system. |

Combined with the basic process of equipment effectiveness evaluation, this paper studies and analyzes the application of effectiveness evaluation method in each stage of evaluation, and enumerates relevant examples to prove it. The research results are helpful for the relevant scholars to understand the current situation of the research on the effectiveness evaluation of the support equipment, and have certain guiding significance for the subsequent research on the effectiveness evaluation of the support equipment.

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