Journal of Computers Vol. 35 No. 3, June 2024, pp. 53-65
doi: 10.53106/199115992024063503005

A Study on Equipment Support Unit and Its Evaluation Based on The Entropy and Objective Weighting

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Received 2 January 2023; Revised 28 January 2023; Accepted 30 January 2023

Abstract. When a new system is developed, it is necessary to select the optimal scheme through system analysis, and how to evaluate the effectiveness of the system is a key link. In order to create conditions for the practical application of system effectiveness evaluation, the effectiveness evaluation method of support capability of a certain type of equipment is proposed. The theories of subjective and objective weighting method, entropy weight method and cloud model are used to comprehensively evaluate the support effectiveness of a certain type of equipment. The evaluation model of support effectiveness of a certain type of equipment is constructed, the basic steps of support effectiveness evaluation are discussed. The evaluation results subordinate cloud of equipment support effectiveness has been obtained. This method successfully evaluates the support effectiveness of a certain type of equipment, the evaluation result is intuitive, and solves the problem of inaccurate support effectiveness evaluation. The example results show that this method is objective, accurate and operable, which can serve the decision-making of equipment support and establish the foundation of improvement research of a certain type of equipment safeguard effectiveness.

Keywords: equipment support, efficiency, evaluation

1 Introduction

Accurate and objective evaluation of equipment support effectiveness is of great significance to equipment optimization design, command decision-making and equipment system construction. Accurate evaluation of system effectiveness can provide objective and quantitative data for equipment development, and avoid waste of human, material and financial resources. Scholars have carried out many weapon equipment support evaluation practices. Some operable evaluation methods were proposed, many research results were achieved.

Scholars researched the equipment support effectiveness evaluation in combination with their own work and tasks. Many researchers have applied many methods to evaluate system effectiveness, including analytic hierarchy process, entropy weight method, simulation experiment method, battle ring theory, etc [1, 2]. Wang et al. [3] established the efficiency requirement model for C4ISR system and realized the system efficiency analysis by using the efficiency evaluation function based on the cloud model. Qian et al. [4] established an army wide operational effectiveness evaluation system. The operational effectiveness of the system was evaluated. Ma et al. [5] combined the contribution evaluation model of the weapon system and evaluated the combat effectiveness of the system by using the confidence rule reasoning method. Luo et al. [6] established the network model of the combat system using the combat ring theory, and evaluated the combat effectiveness of the system using the information entropy theory. Wei et al. [7] used the improved information entropy effectiveness evaluation method to evaluate the operational effectiveness of the system, and verified the evaluation results with examples. Huan et al. [8] used the functional dependency network analysis (FDNA) method to evaluate the effectiveness of complex systems, and took the sea air defense and anti missile system as an example to verify the proposed method. Liu et al. [9] established an evaluation system of aviation equipment maintenance support capability, and used the improved entropy method and cloud model theory to evaluate support effectiveness. Liang et al. [10] determined the objective weight of experts according to the judgment information of experts, and verified the proposed method with examples. Zhu et al. [11] established an evaluation system of equipment maintenance support capability, and used cloud matter-element theory, entropy weight method and mean square error method to evaluate equipment support capability. Wang et al. [12] evaluated the effectiveness of the equipment support system by

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establishing an asymmetric grey cloud model, and the evaluation results were relatively objective. Wang et al. [13] used the grey cloud clustering comprehensive evaluation model to evaluate the reliability of the guidance simulation system and verified the effectiveness of the method. Xu et al. [14] established an evaluation system of space equipment support capability, and used various evaluation methods to evaluate the support effectiveness of space equipment. Zhang et al. [15] established an air defense operational efficiency index system for surface ships in a complex electromagnetic environment, and used AHP method to evaluate the operational efficiency. Wang et al. [16] established the maintenance quality model of complex equipment, and realized the maintenance quality evaluation of complex equipment. Tian et al. [17] combined the nature of the indicators, used the methods of qualitative analysis and quantitative analysis, objectively determined the weights of multiple indicators, and verified the proposed method with examples.

The concept of “performance-based support” proposed by the US military means that the equipment support effectiveness evaluation system has begun to be established. The US military has not only established a capability based requirements analysis method, but also formed a new method and process to meet the needs of future equipment development. In the “International Procedure Specification for Logistics Support Analysis” issued by the European Association of Aerospace and Defense Industries, the supportability requirements are defined qualitatively and quantitatively. Au et al. [18] studied how to improve the operational effectiveness of joint forces, and analyzed and evaluated the operational effectiveness of abstract operational models. Dillenburger et al. [19] used an analysis method to successfully determine the optimal Pareto front in the multi-target air attack, ensuring the success of the accurate air attack. Hocaoğlu [20] studied the problem of allocating air defense missiles to incoming air targets to maximize the air defense effectiveness of land-based air defense systems. Jung et al. [21] used big data and virtual simulation methods to evaluate the effectiveness of the weapon system and found important factors that affect the effectiveness of the weapon system. Daneshvar et al. [22] used the combination of fuzzy set theory, analytic hierarchy process (AHP) and data envelopment analysis (DEA) to deal with the uncertainty in the system assessment, which improved the reliability of risk assessment.

In the study of modeling and effectiveness evaluation, it is found that the decision information supporting the evaluation of support capability has certain incompleteness, randomness and fuzziness. Traditional effectiveness evaluation methods are difficult to deal with the randomness and fuzziness of indicators. The weakness of AHP is that the hierarchy model cannot describe other relationships within the hierarchy, which will affect the final results of the system effectiveness evaluation in some specific scenarios. The simulation evaluation method requires a high level of computer simulation platform, which is relatively difficult to realize.

For complex systems, the combat ring theory can be used to evaluate the effectiveness of the system. The number of combat rings is used as the index to measure the effectiveness of the system. However, the heterogeneity of nodes in the system is not fully considered in the evaluation process, and the effectiveness evaluation results are inaccurate. Due to the complexity of the system composition, various influencing factors are intertwined, and the complexity, diversity, transient and unpredictability of the use environment bring difficulties to the traditional system effectiveness evaluation method, which affects the effectiveness evaluation results. When dealing with randomness and fuzziness, cloud model theory can integrate randomness and fuzziness, and obtain effectiveness evaluation results that belong to the cloud, which intuitively reflects the effectiveness evaluation results. Cloud model theory is widely used in effectiveness analysis.

In view of the uncertainty in the weighting process, the improved GAHP method was used to give weight to the indicators, which can better integrate the opinions of multiple experts. The entropy weight method was improved to calculate the objective weight of indicators. The comprehensive weight of indicators was calculated by subjective and objective weighting method. Aiming at the problem that the evaluation index system of equipment support capability was not comprehensive enough, the factors that affect the equipment support capability were analyzed and studied. The principles of hierarchy, scientificity, qualitative and quantitative were comprehensively considered to build an evaluation model for a certain type of equipment. In view of the uncertainty in the process of raw data processing and evaluation, the cloud model evaluation method was adopted, and the indicators were evaluated.

2 Analysis Method of Subjective and Objective Weight Index

2.1 Determination of Subjective Weight

Firstly, subjective weighting was carried out. In the weighting process, due to the different experiences and working backgrounds of many experts, the judgment matrices obtained may be quite different. Clustering and European distance were used to obtain reasonable subjective weights.

Calculation of Compatibility between Experts. If the weight of multiple experts without weight is $W_i = \left(w_{i1}^0, w_{i2}^0, \cdots, w_{in}^0\right)^T$, $i = (1, 2, \ldots, m)$, m represents the number of experts and n represents the number of indicators. The weight of each expert was obtained by classifying the experts. Expert x and y gived judgment matrix $A_x = \left(a_{ij}^x\right)_{n\times n}$ and $A_y = \left(a_{ij}^y\right)_{n\times n}$. The weight vector is $W_x = (w_{x1}, w_{x2}, \ldots, w_{xn})^T$, $W_y = (w_{y1}, w_{y2}, \ldots, w_{yn})^T$. Then cluster manipulation was carried out, and similarity coefficient could measure the similarity between variables. Compatibility $c\,(x, y)$ is the similarity coefficient between W_x and W_y, it is defined as:

$$c(x, y) = \frac{\sum_{k=1}^{n} w_{xi} \times w_{yi}}{\sqrt{(\sum_{i=1}^{n} w_{xi}^2) \times (\sum_{i=1}^{n} w_{yi}^2)}} \,. \tag{1}$$

The consistency matrix $E\,(c(x, y))_{m\times m}$ is calculated by the expert consistency and weight vector. The consistency between experts and the average distance between classes are used to get the clustering results of experts.

Calculation Method of Expert Weight.

(1) Weight between categories of multiple experts

When calculating the weight among multiple experts, it is assumed that m experts are divided into L types. The category of expert i is G_l. The number of experts in this category is φ_l. Category l experts and their correction coefficient, which can be taken as 0.5. The difference of consistency between experts of category l and other categories is D_l. The weight coefficient between categories is calculated by the following formula:

$$\alpha_l = \frac{\varphi_l^2}{D_l} \cdot \frac{1}{\sum_{i=1}^{L} \frac{\varphi_l^2}{D_l}} \,. \tag{2}$$

(2) Weight of experts in the category

When determining the weight of experts in the category, assume that the number of experts in the category of the expert i is φ_l ($\varphi_l \le m$), classification number is L. The weight of the ith expert is α_i, b is the scale factor, b can be taken as 10, CR_i is the consistency proportion of the ith expert judgment matrix. The weight of experts in the category is calculated by the following formula:

$$\beta_i = \frac{1/\left(1 + b \times CR\right)}{\sum_{j=1}^{\varphi_l}\left(1/\left(1 + b \times CR_j\right)\right)} \left(i = 1, 2, \cdots, m; j = 1, 2, \cdots \varphi_l\right) . \tag{3}$$

(3) Weights of experts after clustering

The weight of experts after clustering can be calculated by the weight of experts between categories and the weight of experts within categories, the formula is as follows:

$$\phi_i = \alpha_l \times \beta_i \left(l = 1, 2, \cdots, L; i = 1, 2, \cdots, m \right) \quad . \qquad (4)$$

Weight Distribution using Euclidean Distance. AHP method is used to calculate the weight of m experts to n indicators. The European distance between two experts is:

$$d_{xy} = d(W_x, W_y) = \sqrt{\sum_{i=1}^{n} (w_{xi} - w_{yi})^2} \quad . \qquad (5)$$

The similarity between the opinions of the ith expert and those of other experts is d_i:

$$d_i = \sum_{j=1}^{m} d_{ij} \quad . \qquad (6)$$

The weight μ_i of the ith expert obtained is as follows:

$$\mu_i = \begin{cases} \frac{1}{m}, d_i = 0 \\ \frac{\frac{1}{d_i}}{\sum_{j=1}^{m} (\frac{1}{d_j})}, d_i \neq 0 \end{cases} \quad . \qquad (7)$$

Calculation Method of Expert Comprehensive Weight. The comprehensive weight of the ith expert is as follows, ε is the correction factor, which can be taken as 0.5:

$$\sigma_i = \varepsilon \phi_i + \left(1 - \varepsilon\right) \mu_i \quad . \qquad (8)$$

Calculation Method of Subjective Weight of Indicators. The subjective weights of the indicators are as follows:

$$W_s = \sum_{i=1}^{m} \sigma_i \times W_i^0 = \left(w_{s1}, w_{s2}, \cdots w_{sn} \right) \quad . \qquad (9)$$

2.2 Evaluation of Objective Weight of Indicators

Entropy weight method was used to calculate, n indicators were evaluated by m experts. The weight matrix $X = (x_{ij})_{m\times n}$ was obtained from the unweighted weights of multiple experts. After $X = (x_{ij})_{m\times n}$ was normalized, the matrix R could be obtained:

$$R = \left(r_{ij} \right)_{m\times n} \left(i = 1, 2, \cdots m; j = 1, 2, \cdots n \right) \quad . \qquad (10)$$

Element r_{ij} in the matrix was the evaluation value of the ith expert on the jth index, $r_{ij} \in [0,1]$. It was corrected to avoid a situation equal to zero:

$$b_{ij} = r_{ij} + 10^{-4} \quad . \tag{11}$$

The weight of the ith expert in the j index could be calculated, matrix $P = (p_{ij})_{m\times n}$ was composed of $p_{ij} = \frac{b_{ij}}{\sum_{i=1}^{m} b_{ij}} \left(i = 1, 2, \cdots, m; j = 1, 2, \cdots, n\right)$.

The matrix $P = (p_{ij})_{m\times n}$ was used to obtain the entropy value H_j and the difference coefficient G_j of the j evaluation indicators as follows:

$$H_j = -\frac{1}{\ln m}\sum_{i=1}^{m} p_{ij} \ln p_{ij} \left(j = 1, 2, \cdots, n\right) \quad . \tag{12}$$

$$G_j = 1 - H_j \left(j = 1, 2, \cdots, n\right) \quad . \tag{13}$$

The objective weight W_o could be calculated by the difference coefficient, where $\sum_{j=1}^{n} W_o = 1$, $0 \le W_o \le 1$.

$$W_o = \frac{G_j + 0.1\sum_{j=1}^{n} G_j}{\sum_{j=1}^{n}\left(G_j + 0.1\sum_{j=1}^{n} G_j\right)} \quad . \tag{14}$$

2.3 Analysis Method of Subjective and Objective Weighting Index

The subjective weight and objective weight of indicators were integrated by using game theory to obtain the comprehensive weight. When there were L methods to assign weight to an indicator, the weight vector could be established as $W_k = \{W_{k1}, W_{k2}, \ldots, W_{km}\}$, $k = 1, 2, \ldots, L$, each vector element was combined to get:

$$\mathrm{W} = \sum_{k=1}^{L} a_k W_k^T \left(a_k > 0\right) \quad . \tag{15}$$

In order to obtain the optimal W^* in vector W, the coefficient was adjusted. The deviation between W and W^* was minimum:

$$\min \left\| \sum_{j=1}^{L} a_j W_j^T - W_i^T \right\| \left(i = 1, 2, \cdots, L\right) \quad . \tag{16}$$

The first derivative of equation (16) was optimal under the following conditions:

$$\sum_{i=1}^{L} a_i W_j W_i^T = W_j W_j^T \quad . \tag{17}$$

The coefficient a_i could be calculated and normalized according to the following formula:

$$a_k^* = \frac{a_k}{\sum_{k=1}^{L} a_k} \quad . \tag{18}$$

The optimal weight vector W^* was:

$$W^* = a_1^* W_s^T + a_2^* W_o^T \quad . \tag{19}$$

3 Cloud Model Aggregation of Evaluation Results

3.1 Preparation of Comment Collection

Comment set V was formulated, several experts were invited to evaluate the equipment support capability, which was divided into {good, relatively good, general, relatively poor, poor} five levels, and the cloud generator was used to obtain the eigenvalue (Ex^0, En^0, He^0) of the V cloud model:

$$\begin{cases} Ex_{ij} = (R_{j\max}^i + R_{j\min}^i)/2 \\ En_{ij} = (R_{j\max}^i - R_{j\min}^i)/6 \\ He_{ij} = k \cdot En_{ij} \end{cases} \quad . \tag{20}$$

Where, $R_j^i = \left(R_{j\min}^i, R_{j\max}^i\right)$, $i = 1, 2, ..., n$, $j = 1, 2, 3, 4, 5$, was the evaluation interval of expert i on comment set j. Ex_{ij}, En_{ij}, He_{ij} were the expected value, entropy value and super entropy calculated by the expert scoring interval. The constant k could be taken as 0.1.

$$\begin{cases} Ex_j = \dfrac{Ex_{1j}En_{1j} + Ex_{2j}En_{2j} + \cdots + Ex_{nj}En_{nj}}{En_{1j} + En_{2j} + \cdots + En_{nj}} \\ En_j = \dfrac{En_{1j}^2 + En_{2j}^2 + \cdots + En_{nj}^2}{En_{1j} + En_{2j} + \cdots + En_{nj}} \\ He_j = \dfrac{He_{1j}En_{1j} + He_{2j}En_{2j} + \cdots + He_{nj}En_{nj}}{En_{1j} + En_{2j} + \cdots + En_{nj}} \end{cases} \quad . \tag{21}$$

When the experts' weights were equal, Ex_j, En_j, He_j represented the expected value, entropy value and super entropy of experts on comment set j.

3.2 Calculation Process of the First Level Indicator Comprehensive Cloud

The comprehensive cloud of primary indicators could be calculated by the weight of primary indicators and secondary indicators. The calculation formula was:

$$\begin{cases} Ex = \dfrac{Ex_1 En_1 W_1^* + Ex_2 En_2 W_2^* + \cdots + Ex_n En_n W_n^*}{En_1 W_1^* + En_2 W_2^* + \cdots + En_n W_n^*} \\ En = En_1 W_1^* + En_2 W_2^* + \cdots + En_n W_n^* \\ He = \dfrac{He_1 En_1 W_1^* + He_2 En_2 W_2^* + \cdots + He_n En_n W_n^*}{En_1 W_1^* + En_2 W_2^* + \cdots + En_n W_n^*} \end{cases} . \quad (22)$$

$W_i^* \left(i = 1, 2, \cdots, q\right)$ refered to the weight of primary indicators, q was the number of primary indicators.

3.3 Generation of Support Effectiveness Evaluation Result Cloud Map

The characteristic value (Ex^*, En^*, He^*) of the first level indicator and the characteristic value (Ex^0, En^0, He^0) of the comment set were input into the positive cloud generator to get the cloud map of the equipment support effectiveness evaluation results, which intuitively reflects the effectiveness evaluation results.

4 Example of Equipment Support Capability Evaluation

According to the use and training of a certain type of equipment at ordinary times, combined with the opinions given by many experts, the factors affecting the equipment support capability were analyzed and studied. The hierarchical, scientific, qualitative and quantitative principles were comprehensively considered to build the indicator system of a certain type of equipment support capability was shown in Fig. 1:

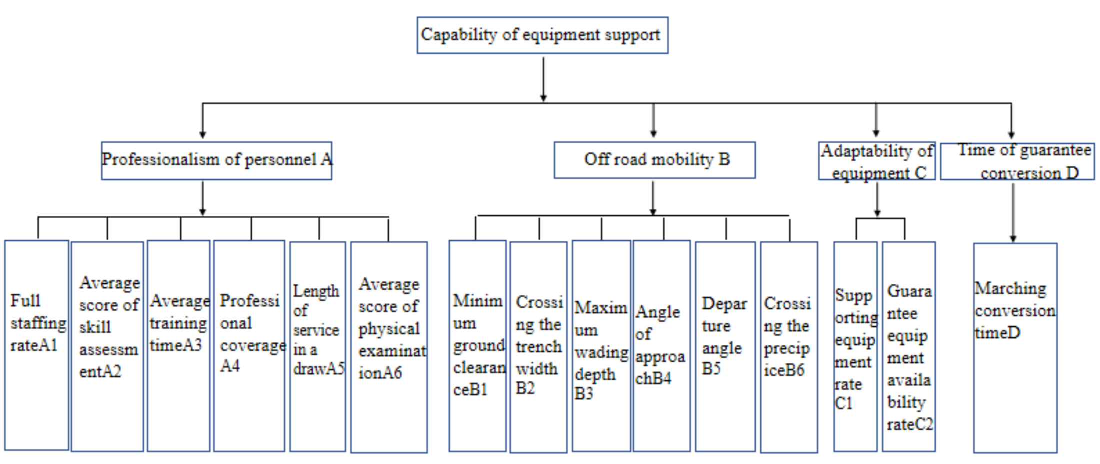


Fig. 1. Support capability index system of a certain type of equipment

The secondary indicators in the system “personnel professionalism A, off-road mobility B, equipment adaptability C and support conversion time D” have no fixed value for the primary indicator “equipment support capability”, so the secondary indicators were qualitative indicators. The weight of the four indicators on equipment support capability could be determined through game theory knowledge.

The equipment support capability evaluation process was shown in Fig. 2. First, the indicator system of certain equipment support capability was established, and the nature of the indicators was distinguished. Experts were invited to score the qualitative indicators. According to the scoring results, the subjective weight of the experts and the objective weight of the indicators were calculated, and then the comprehensive weight of the indicators was determined. Then, the entropy weight method was used to calculate the weight of quantitative indicators.

Finally, a comment cloud model was established, and a positive cloud generator was used to obtain the result of a certain type of equipment support effectiveness evaluation that belongs to the cloud.

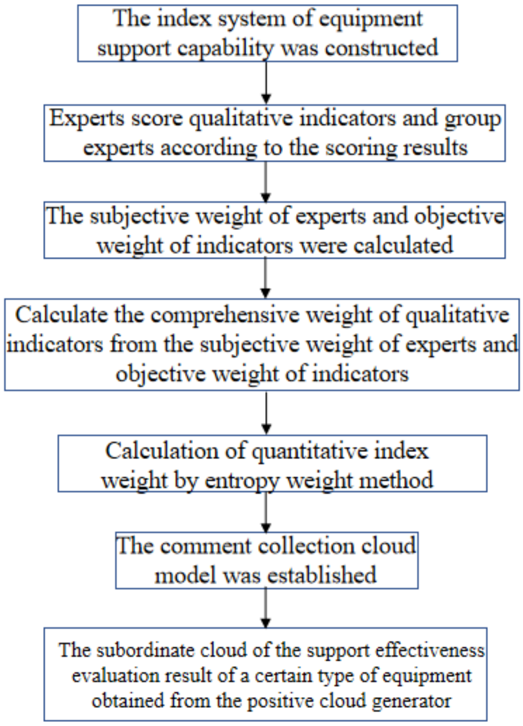


Fig. 2. Evaluation process of equipment support capability

4.1 Calculation of Weight

Calculation of Subjective Weight. Eight experts were invited to score the first level indicators, and the judgment matrix was as follows:

$$\begin{bmatrix} 1 & 1 & 0.5 & 1 \\ 1 & 1 & 0.5 & 2 \\ 2 & 2 & 1 & 2 \\ 1 & 0.5 & 0.5 & 1 \end{bmatrix} \begin{bmatrix} 1 & 1 & 0.5 & 1 \\ 1 & 1 & 0.33 & 2 \\ 2 & 3 & 1 & 2 \\ 1 & 0.5 & 0.5 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 1 & 0.5 & 0.5 \\ 1 & 1 & 0.5 & 2 \\ 2 & 2 & 1 & 2 \\ 2 & 0.5 & 0.5 & 1 \end{bmatrix} \begin{bmatrix} 1 & 1 & 1 & 0.5 \\ 1 & 1 & 0.5 & 1 \\ 1 & 2 & 1 & 3 \\ 2 & 1 & 0.33 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 1 & 0.5 & 1 \\ 1 & 1 & 0.5 & 2 \\ 2 & 2 & 1 & 2 \\ 1 & 0.5 & 0.5 & 1 \end{bmatrix} \begin{bmatrix} 1 & 1 & 0.33 & 0.5 \\ 1 & 1 & 0.5 & 2 \\ 3 & 2 & 1 & 2 \\ 2 & 0.5 & 0.5 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 1 & 1 & 0.3 \\ 1 & 1 & 0.3 & 2 \\ 1 & 3 & 1 & 2 \\ 3 & 0.5 & 0.5 & 1 \end{bmatrix} \begin{bmatrix} 1 & 1 & 0.5 & 1 \\ 1 & 1 & 0.33 & 2 \\ 2 & 3 & 1 & 2 \\ 1 & 0.5 & 0.5 & 1 \end{bmatrix}$$

Different experts have different opinions and opinions on an index. According to the method in literature [23], the unweighted index weights are as follows:

$$W_1^0 = (0.1980,\ 0.2390,\ 0.3950,\ 0.1680)$$

$$W_2^0 = (0.1900,\ 0.2130,\ 0.4320,\ 0.1650)$$

$$W_3^0 = (0.1680,\ 0.2420,\ 0.3860,\ 0.2040)$$

$$W_4^0 = (0.2070,\ 0.1890,\ 0.3810,\ 0.2220)$$

$$W_5^0 = (0.1980,\ 0.2390,\ 0.3950,\ 0.1680)$$

$$W_6^0 = (0.1500,\ 0.2370,\ 0.4160,\ 0.1970)$$

$$W_7^0 = (0.1840,\ 0.2170,\ 0.3640,\ 0.2350)$$

$$W_8^0 = (0.1900,\ 0.2130,\ 0.4320,\ 0.1650)$$

(1) Equation was used to calculate the expert compatibility degree, and the expert compatibility matrix was obtained as shown in Fig. 3(a). The maximum distance method was used for analysis. The 8 experts were divided into several groups. The grouping was shown in Fig. 3(b). It could be seen from the figure that the fourth expert and the seventh expert were a group, and the rest were a group.

From equation (2) to equation (4), the expert weight value after clustering was calculated as:

$$\varphi = \left(0.0382,\ 0.1461,\ 0.0261,\ 0.1883,\ 0.1532,\ 0.1793,\ 0.1227,\ 0.1461\right)$$

From Eq. (5) to Eq. (7), the expert weight was calculated by Euclidean distance:

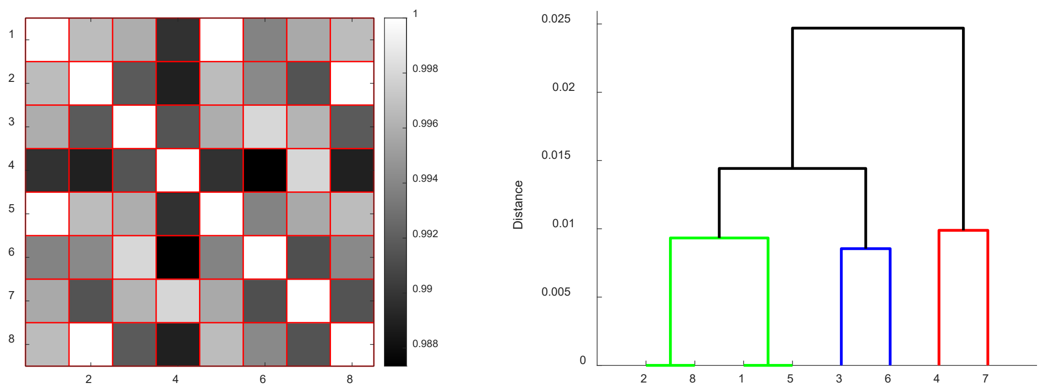
$$\mu = \left(0.1458,\ 0.1285,\ 0.1325,\ 0.1008,\ 0.1458,\ 0.1185,\ 0.0995,\ 0.1285\right)$$

According to formula (8), the comprehensive weight of experts was:

$$\sigma = \left(0.0920,\ 0.1373,\ 0.0793,\ 0.1446,\ 0.1495,\ 0.1489,\ 0.1111,\ 0.1373\right)$$

According to formula (9), the subjective weight vector of experts was:

$$W_s = \left(0.1860,\ 0.2221,\ 0.4021,\ 0.1896\right)$$



(a) Matrix graph of compatibility degree

(b) Pedigree of expert

Fig. 3. Compatibility matrix and clustering pedigree of experts

Calculation of Objective Weight. According to the equipment support capability index system, personnel professionalism A, off-road mobility B, equipment adaptability C and support conversion time D were scored.

From Eq. (10) to Eq. (14), the objective weights were as follows:

$W_0 = (0.2431,\ 0.1919,\ 0.1345,\ 0.4305)$

Determination of Comprehensive Weight of Indicators. According to the subjective and objective weights of experts and formulas (15)~(19), the combination coefficient and comprehensive weight were:

$a_1^* = 0.4487,\ a_2^* = 0.5513$

$W^* = \left(0.2175,\ 0.2055,\ 0.2546,\ 0.3224\right)$

Since indicators A1-A6, B1-B6, C1 and C_2 had specific values, they were quantifiable indicators. The process of calculating their indicator weights using entropy weight method was as follows:

Standardized treatment:

$$y_{ij} = \frac{x_j - x_{j\min}}{x_{j\max} - x_{j\min}} \ . \tag{23}$$

y_{ij} represented the jth index value of the ith object after dimensionless processing, x_{ij} was the jth index value of the ith object.

Index standardization:

$$f_{ij} = \frac{y_{ij}}{\sum_{i=1}^{n} y_{ij}} \ . \tag{24}$$

Calculation of information entropy of indicators:

$$\mathrm{H_i} = -k\sum_{j=1}^{n} f_{ij} \ln f_{ij} \ . \tag{25}$$

$$f_{ij} = \frac{r_{ij}}{\sum_{j=1}^{n} r_{ij}} ; k = \frac{1}{\ln n} \ . \tag{26}$$

Calculation of entropy weight of the ith index:

$$w_i = \frac{1 - H_i}{m - \sum_{i=1}^{m} H_i} \ . \tag{27}$$

The evaluation matrices R1, R2 and R3 of A1~A6, B1~B6, C1 and C2 were calculated and standardized:

$$R_1 = \begin{pmatrix} 0.62 & 0.68 \\ 0.74 & 0.76 \\ 0.78 & 0.72 \\ 0.82 & 0.87 \\ 0.80 & 0.76 \\ 0.77 & 0.83 \end{pmatrix}$$

$$R_2 = \begin{pmatrix} 0.73 & 0.68 \\ 0.82 & 0.80 \\ 0.79 & 0.83 \\ 0.68 & 0.75 \\ 0.87 & 0.83 \\ 0.79 & 0.77 \end{pmatrix}$$

$$R_3 = \begin{pmatrix} 0.82 & 0.86 \\ 0.76 & 0.79 \end{pmatrix}$$

The formula of entropy weight method was used to calculate the weight of C1 and C2 to C as (0.6021,0.3979). The weight of A1~A6 to A was (0.3111, 0.0260, 0.2337, 0.1278, 0.0960, 0.2054). The weight of B1~B6 to B was (0.2449, 0.0297, 0.1187, 0.4668, 0.1078, 0.0320). The comprehensive weight of each indicator layer for the target layer was as follows:

$$\begin{pmatrix} 0.3111 & 0 & 0 & 0 \\ 0.0260 & 0 & 0 & 0 \\ 0.2337 & 0 & 0 & 0 \\ 0.1278 & 0 & 0 & 0 \\ 0.0960 & 0 & 0 & 0 \\ 0.2054 & 0 & 0 & 0 \\ 0 & 0.2449 & 0 & 0 \\ 0 & 0.0297 & 0 & 0 \\ 0 & 0.1187 & 0 & 0 \\ 0 & 0.4668 & 0 & 0 \\ 0 & 0.1078 & 0 & 0 \\ 0 & 0.0320 & 0 & 0 \\ 0 & 0 & 0.6021 & 0 \\ 0 & 0 & 0.3979 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} 0.2175 \\ 0.2055 \\ 0.2546 \\ 0.3224 \end{pmatrix} = \begin{pmatrix} 0.0677 \\ 0.0057 \\ 0.0508 \\ 0.0278 \\ 0.0209 \\ 0.0447 \\ 0.0503 \\ 0.0061 \\ 0.0244 \\ 0.0959 \\ 0.0222 \\ 0.0066 \\ 0.1533 \\ 0.1013 \\ 0.3224 \end{pmatrix}$$

4.2 Comment Cloud Model

The first level indicators of the equipment support capability indicator system model are qualitative indicators. Eight experts are invited to evaluate them according to the five levels of “poor, relatively poor, general, relatively good, and good”. “poor” means that the demand cannot be met at all, “relatively poor” means that the demand cannot be met, “general” means that the demand is basically met, “relatively good” means that the demand can be met, and “good” means that the demand can be met completely. Table 1 shows the evaluation intervals of each expert. According to Eq. (20) and Eq. (21), the characteristic values of comment set are shown in Table 2.

Table 1. Estimated interval value of comments

	Poor	Relatively poor	General	Relatively good	Good
1	(0.20, 0.45)	(0.46, 0.65)	(0.66, 0.75)	(0.76, 0.89)	(0.90, 0.90)
2	(0.20, 0.40)	(0.41, 0.55)	(0.56, 0.79)	(0.80, 0.89)	(0.89, 0.99)
3	(0.15, 0.35)	(0.36, 0.59)	(0.60, 0.79)	(0.80, 0.85)	(0.86, 0.99)
4	(0.10, 0.35)	(0.36, 0.60)	(0.61, 0.65)	(0.66, 0.84)	(0.85, 0.99)
5	(0.20, 0.40)	(0.41, 0.55)	(0.56, 0.70)	(0.71, 0.89)	(0.90, 0.99)
6	(0.15, 0.35)	(0.36, 0.59)	(0.60, 0.75)	(0.76, 0.84)	(0.85, 0.95)
7	(0.20, 0.40)	(0.41, 0.55)	(0.56, 0.74)	(0.75, 0.89)	(0.90, 0.99)
8	(0.10, 0.29)	(0.30, 0.59)	(0.60, 0.70)	(0.71, 0.89)	(0.90, 0.98)

Table 2. Eigenvalues of level 5 comments

	Poor	Relatively poor	General	Relatively good	Good
Ex^0	0.2780	0.4935	0.6647	0.8084	0.9301
En^0	0.0354	0.0365	0.0274	0.0217	0.0170
He^0	0.0035	0.0037	0.0027	0.0022	0.0017

Table 3. Characteristic value of level 1 Index cloud model

Index	Eigenvalue of cloud model (Ex^*, En^*, He^*)	Index	Eigenvalue of cloud model (Ex, En, He)
A	(0.8009, 0.0284, 0.0028)	B1	(0.7350, 0.0329, 0.0033)
		B2	(0.8231, 0.0281, 0.0028)
		B3	(0.8131, 0.0276, 0.0027)
		B4	(0.8423, 0.0263, 0.0025)

The characteristic values of the cloud model of the primary indicator obtained from equation (23) are shown in Table 3. The subordinate cloud of the support effectiveness evaluation result of a certain type of equipment can be obtained from the positive cloud generator, as shown in Fig. 4. It can be seen from the figure that the support effectiveness is between "good" and "relatively good", and close to "relatively good", indicating that the effectiveness evaluation result of the support capability index system of a certain type of equipment is within the "relatively good" range.

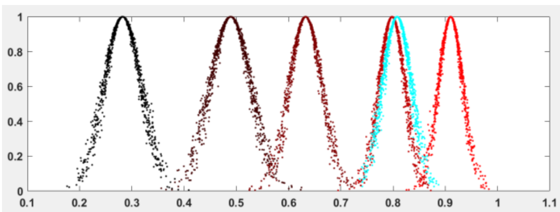


Fig. 4. The subordinate cloud of the support effectiveness evaluation result of a certain type of equipment

5 Conclusion

In this paper, the three-level equipment support capability evaluation model was established, and the nature of each index in the model was distinguished. The weight of each index was scientifically determined by using subjective and objective weighting method and entropy weight method, and the support effectiveness of a certain type of equipment was evaluated by using the cloud model theory. The research results could be applied to the effectiveness evaluation of equipment support capability and promote the optimization design of equipment. In practical application, the effectiveness of different equipment support systems could be evaluated to improve the decision-making level of equipment support.

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