Research on Equipment Support Capability Evaluation based on Information Fusion

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Abstract: The evaluation of equipment support capability cannot be ignored in the work of equipment support, and the evaluation results directly affect the formulation and decision-making of the support scheme. In view of the multi-source uncertain information in the process of evaluation, this paper proposes an equipment support capability evaluation model based on information fusion, and uses the D-S evidence theory to model and evaluate the uncertainty. The results show that the proposed method is effective. It can be used in engineering practice.

1. Introduction
The evaluation of equipment support capability is an important part of the equipment support work. It is beneficial to grasp the level of equipment support capability accurately and timely, and to make a decision according to the plan. And then improve the equipment support capability [1].

The evaluation of equipment support capability involves multi-source information. How to effectively fuse and make effectively use this information need the information fusion technology [2]. Information fusion technology can effectively integrate all kinds of support information, it is conducive to improve the level of equipment support. At present, Bayes theory, D-S evidence theory, neural network, fuzzy theory, rough set theory, support vector machine, information entropy and other methods are widely used [3]. Literature [4-7] studied the evaluation of equipment support capability from different aspects, and tried to evaluate the capability of equipment support dynamically, and achieved good results. However, most of the above research models are qualitative analysis, and no personnel quality and other indicators to be considered.

Among the many evaluation methods, the D-S evidence theory can deal with the uncertain information well, and does not need a priori probability, so this paper intends to use the D-S evidence theory to evaluate the equipment support capability. From the quantitative aspect, the evaluation results are more scientific and reasonable.

2. Basic Concepts of Evidence Theory
D-S evidence theory is an uncertain, inexact reasoning method.

Suppose there is an event that needs to be adjudicated, and all sets of possible answers that people may recognize about the existence of this event are represented, and, in the case of an event, it is defined as an identification framework Θ. Θ represents a set of these incompatible complete assumptions, which can be represented by formula (1) as:
\[ \Theta = \{ \theta_1, \theta_2, \cdots, \theta_j, \cdots, \theta_n \} \]  \hspace{1cm} (1)

\( \theta_j \) represent an element or event under \( \Theta \).

Definition 1: Suppose that in the recognition framework \( \Theta \), if the set function \( m: 2^n \rightarrow [0, 1] \) represents a mapping from the set \( 2^n \) to an interval power set \([0, 1]\), the following conditions are satisfied:

\[ m(\emptyset) = 0 \] \hspace{1cm} (2)

\[ \sum_{A \subseteq \Theta} m(A) = 1 \] \hspace{1cm} (3)

Then we call \( m \) the basic probability assignment function on the recognition framework \( \Theta \).

Definition 1-2: assuming that in the recognition framework \( \Theta \). \( m: 2^n \rightarrow [0, 1] \) is the basic belief assignment function on the recognition framework \( \Theta \), the function \( Bel: 2^\Theta \rightarrow [0, 1] \) defined by formula (4) is called the belief function on the recognition framework \( \Theta \).

\[ Bel(A) = \sum_{B \subseteq A} m(B) \quad (\forall A \subseteq \Theta) \] \hspace{1cm} (4)

Suppose that \( E1, E2 \) is two evidences under the recognition framework \( \Theta \) respectively, and that \( Bel_1, Bel_2 \) is two belief functions on the same recognition framework, \( m_1, m_2 \) is the basic probability assignment function corresponding to the two evidences, and the focal element is \( A_1, \cdots, A_k \) and \( B_j, \cdots \). If:

\[ \sum_{A \subseteq \Theta, \ A \neq \emptyset} m_1(A) m_2(B_j) < 1 \] \hspace{1cm} (5)

Then the Dempster combination rule is:

\[ m(A) = \begin{cases} 0 & A = \emptyset \\ \frac{\sum_{A \subseteq \Theta, \ A \neq \emptyset} m_1(A) m_2(B_j)}{1 - k} & A \neq \emptyset \end{cases} \] \hspace{1cm} (6)

In formula (6), \( k = \sum_{A \subseteq \Theta, \ A \neq \emptyset} m_1(A) m_2(B_j) \) is the conflict coefficient, it represents the degree of conflict between the various evidence.

3. Evaluation of Equipment Support Capability based on Evidence Theory

The main processes of equipment support capability assessment include:

Step 1: establish the framework of equipment support capability;
Step 2: select suitable evaluation index for equipment support capability evaluation and establish evidence body at the same time;
Step 3: set the basic belief assignment value of each evidence body;
Step 4: use evidence theory to combine evidence;
Step 5: make a comprehensive decision based on the combination results.

The process is shown in figure 1.
Evaluation of equipment support capability based on D-S evidence theory

Establish the framework of equipment support capability

Select evaluation index and establish evidence body

Set the basic Belief assignment value

Use evidence theory to combine evidence

Comprehensive decision based on the Combination results

**Figure 1.** Evaluation process of equipment support capability based on evidence theory

### 3.1. Construction of the Framework

The support capability of the equipment is divided into four grades: excellent, good, moderate and poor. Under the frame \( \Theta \), it is expressed as \( \Theta = \{A,B,C,D\} \).

### 3.2. Selection of Equipment Support Capability Index

According to the literature [8], this paper selects manpower, supply support, technical information and facilities as the relatively independent evidence to measure the equipment support capability. Because the importance of different indicators is different, it is necessary to give different weights to different indicators to make the evaluation results more accurate.

### 3.3. Construction of the Basic Belief Function

The weights of different indexes are obtained by the expert scoring method, and the values are in the range of 0-1. \( w(i) \) represents the weights of different levels. The membership of the index \( i \) belonging to the grade \( j \) is taken as the basic probability distribution value of the index. \( m_i(j) \) represent the basic probability distribution value of the index \( i \) belonging to grade \( j \).

### 3.4. Combination of Evidence

Because the weights of different indexes are different, it is necessary to consider the different weights and to modify the above formula. In this paper, the unified belief function model proposed in [9] is used, as shown in formula (7).

\[
m(A) = \sum_{B \in A} m(B) \cdot m_i(C) + k \cdot \delta(A,m)
\]  

(7)

In formula (7) \( k = \sum_{B \in A} m(B) m_i(C) \) is the total conflict of evidence; represents the weight of the conflict assigned to the evidence and satisfies:

\[
\sum_{A \in m} \delta(A,m) = 1 , \delta(A,m) = \sum_{i=1}^n w(i) m_i(A)
\]
3.5. Determination of the Level of Support Capacity

The final evaluation level of equipment support capability is determined by using the decision method of maximum basic reliability function. In other words, among the four values, the highest value is the grade of equipment support capability.

4. Simulation Verification

Suppose that the planning support resource capability of a naval equipment support base is classified into four grades: excellent, good, medium and poor. It is represented under the recognition framework as $\Theta = \{A, B, C, D\}$. The evaluation indicators include manpower, supply support, technical data and facilities, and support materials. Its weight is $w = \{0.5, 0.2, 0.2, 0.1\}$ . The basic probability assignment for different indicators are shown in Table 1.

| Indicator | A  | B  | C  | D  |
|-----------|----|----|----|----|
| $m_1$     | 0.40 | 0.30 | 0.20 | 0.10 |
| $m_2$     | 0.30 | 0.50 | 0.10 | 0.10 |
| $m_3$     | 0.35 | 0.45 | 0.10 | 0.10 |
| $m_4$     | 0.55 | 0.10 | 0.25 | 0.10 |

According to formula (7), the evidence is combined and the results are shown in Table 2.

| Evidence | A  | B  | C  | D  |
|----------|----|----|----|----|
| $m_{12}$ | 0.4700 | 0.2900 | 0.1600 | 0.0800 |
| $m_{123}$| 0.5050 | 0.2667 | 0.1522 | 0.0761 |
| $m_{1234}$| 0.6027 | 0.1567 | 0.1680 | 0.0726 |

To make the results more intuitive, a histogram is made as shown in figure 2.

![Resultant histogram](https://example.com/histogram.png)

From the above chart we can see, $m_{1234}(A) = 0.6027$, $m_{1234}(B) = 0.1567$, $m_{1234}(C) = 0.1680$, and $m_{1234}(D) = 0.0726$. The support capability is at the maximum belief value of grade A, so it can be considered as excellent.

5. Summary

The evaluation of equipment support capability needs to be fused with multi-source information. This paper proposes an evaluation model of equipment support capability based on information fusion, which uses D-S evidence theory to deal with uncertain problems to evaluate and model, and simulates and verifies it with a numerical example. The results show that the method proposed in this paper is suitable for equipment support capability evaluation and can be used in engineering practice.
Because there are many factors involved in equipment support capability evaluation, only a few models are selected in this paper, which are not comprehensive enough and need further study. At the same time, there is no further distinction between factors, need to be further improved.

6. Reference

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