Application of fuzzy comprehensive evaluation in weapon equipment systems

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Abstract

Analysis and evaluation of the operational effectiveness of weapon equipment operational systems has always been a complex problem, a study of its evaluation technology is of great significance. Task oriented operation, this paper discusses equipment operational system dynamic integration needs, and discusses the steps and comprehensive performance evaluation method of weapon equipment operational system, made a fuzzy comprehensive evaluation method to better adapt to comprehensive performance evaluation of weapon equipment operational system. According to the characteristics of system evaluation factors, and gives an indicator of quantitative methods established based on analytic hierarchy process and correlation analysis of comprehensive performance evaluation model, based on three types of weapon equipment operational system data, for example, proves the validity of the method.

Keywords: Weapon Equipment Systems, Comprehensive Performance, Combat Effectiveness, Multi-level Fuzzy comprehensive evaluation

1 Introduction

With the weapons and equipment have been modernized and weapons and equipment the ability to play in the combat system, military experts alone, intuition and experience to evaluate, it is impossible to meet the requirements of high-tech war under the current conditions, fast, accurate and effective equipment operation evaluation methods have become weapons and equipment development is bound to ask. Evaluation of weapon equipment operational capability is the planning, development, equipment and weaponry deployment and operational application of important links. Played by weapons and equipment in the course of actual combat capability, mainly using operational effectiveness is measured by the weapons and equipment of combat missions performed by. Measure of the weapon equipment operational effectiveness in the combat system is one of the weapons and equipment of the most important assessment parameters; it can reflect the essential characteristics of the weapons and equipment in combat system. In the current world, military equipment operational effectiveness evaluation has become a research and development facility equipped with a "hot" topic. The operational effectiveness evaluation of equipment, equipment, combat simulation, simulation technology has played a key role in the application of, but as the battlefield situation information under the condition of information needs, simulation, simulation applications there are some new issues that cannot be resolved, For example, in the "linear features", "dimensions of disaster" and "complexity of disaster" features such as handling performance in particular.

This article in the previous study of weapon equipment operational system operational effectiveness based on the analysis, considering the issue and proceed from the characteristics of weapon equipment operational effectiveness, presented to the operational effectiveness of weapon equipment operational system analysis of comprehensive evaluation method using fuzzy comprehensive evaluation method to build weapons and equipment effectiveness evaluation model and evaluation system of weapon equipment operational system effectiveness is given.

2 Operational effectiveness evaluation of weapon equipment operational system processes

Weaponry in combat system performance evaluation, not only demand for weapons and equipment appeared a clear understanding of the root of the problem, also need clear evaluation of data sources to determine what assessment methods are used, and map out the equipment operational effectiveness evaluation process to guide the evaluation studies. Literature [1] gives the typical evaluation of weapon equipment operational effectiveness evaluation processes (for example, as shown in Figure 1).

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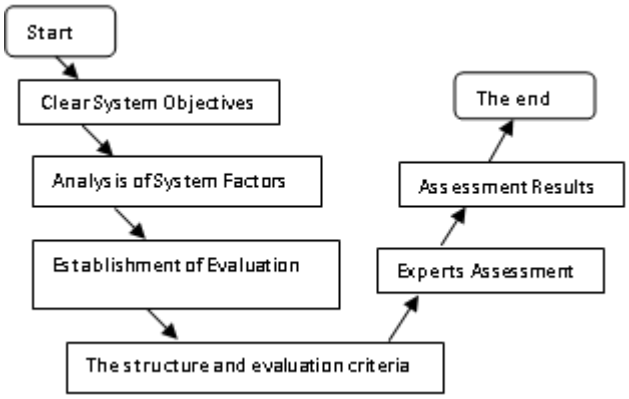


FIGURE 1 The evaluation of weapon equipment operational effectiveness processes

The above (Figure 1) evaluation processes in the area of evaluation of weapon equipment operational effectiveness is widely used, but it also has its disadvantages:

1) The lack of feedback loops in the middle of the evaluation process; it is a one-way assessment process. Satisfaction evaluation system needs to be able to pass a reasonable assessment came over and over again, and the process is repeated evaluation of the loop can be adjusted; one evaluation process is unable to meet this requirement.
2) The fixed evaluation of data sources. Conventional evaluation methods, mainly fixed data source select static analysis results after processing. However in the actual equipment operational evaluation in the course of its data sources are constantly changing. So fixed evaluation of data sources for in-depth evaluation studies, limitations are made, it is difficult to find variation occurring in the evaluation process.

3 Operational effectiveness evaluation model of weapon equipment operational system

3.1 THE OPERATIONAL EFFECTIVENESS EVALUATION OF KEY LINKS

The key elements of weapon equipment operational effectiveness evaluation system is mainly reflected in: evaluation model of the system of indicators, evaluation parameters determining the calculation of indicators, evaluation parameters and performance evaluations. Evaluation of operational effectiveness for weapon equipment operational system currently, probability models, the classic method of ADC, SCA based on Cybernetics and its index model method [2]. Evaluation modelling is the key to the evaluation process, as a Department of weapon equipment operational effectiveness evaluation of programmed implementation and evaluation parameters of calculation on the assumption; it maps the evaluation for effectiveness evaluation model, effective formative assessment solution scenarios.

The application of fuzzy comprehensive evaluation in the weapon equipment operational system focuses on how to determine the weaponry of scientific rationality and the weight of evaluating indicators in combat system. Method for determining the weights of the evaluation indexes for three main categories [3]:

1) *Subjective weighting method.* Mainly, expert investigation of binomial coefficients, APH analytic [4] and the least square method.
2) *The weight method.* Mainly includes: multi-objective programming method, entropy method, component analysis, etc.
3) *The method of combination weighting*. Combination weighting method is to use a combination of subjective and objective weighting method uses a weighting method, perform two weighting method advantages. Equipment operational review process, we use fuzzy consistent matrix to determine weight, avoiding the APH AHP analysis on the adjustment problems of inconsistency of judgment matrix.

3.2 FUZZY COMPREHENSIVE EVALUATION METHOD

1) *Target set.* The target set for $u=(u_1,u_2,\cdots,u_n)$.
2) *Evaluation set.* The evaluation set for $v=(v_1,v_2,\cdots,v_n)$.
3) *Fuzzy comprehensive evaluation model* [5, 6]. Due to the a-level fuzzy comprehensive evaluation:

$$B=(b_1,b_2,\cdots b_m)=(a_1,a_2,\cdots;a_n)\begin{pmatrix} r_{11} & r_{12} & \cdots r_{1m} \\ r_{21} & r_{22} & \cdots r_{2m} \\ r_{n1} & r_{n2} & \cdots r_{nm} \end{pmatrix}. \quad (1)$$

$$0\le r_{ij}\le 1$$

The comprehensive evaluation of the first, after judge sets is going to judge the result as a single factor, two-level fuzzy comprehensive evaluation, whose formula is:

$$C=A\bullet B=\begin{bmatrix} A_1\bullet R_1 \\ A_2\bullet R_2 \\ \vdots \\ A_n\bullet R_n \end{bmatrix}=A\bullet\begin{bmatrix} B_1 \\ B_2 \\ \vdots \\ B_n \end{bmatrix}=A\bullet\left(b_{ij}\right)_{n\times m}. \quad (2)$$

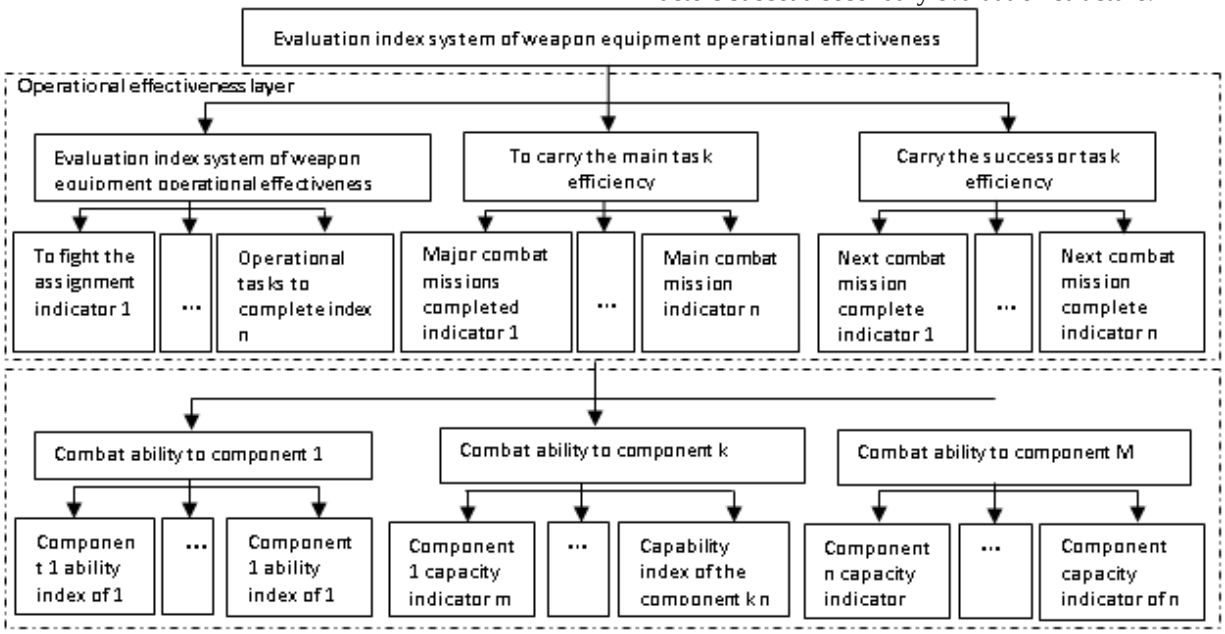
3.3 MODEL SYSTEM OF WEAPON EQUIPMENT OPERATIONAL EFFECTIVENESS

The equipment operation system effectiveness assessment is mainly on programmers of different weaponry systems and systems analysis, comparison; you

need to identify measure indicators. Indicators and combat effectiveness evaluation of weapon equipment operational tasks are closely related and, therefore, have appropriate characteristics, such as indicators to reflect the end of Figure thing, Figure thing for different purposes, their efficiency evaluation indicators are also different; indicators to reflect the randomness of combat, using a probabilistic nature of digital character to represent; indicators to reflect the complexity of the battle, with gradation and diversity. Armed combat system effectiveness evaluation by using the method of fuzzy comprehensive evaluation for effectiveness evaluation. First of all, to levels of operational efficiency evaluation systems of all kinds of weapons into fuzzy subset defines evaluation levels:

$$V=\{v_1,v_2,v_3,v_4,v_5\}. \tag{3}$$

Equipment operation system effectiveness assessment is divided into five levels: excellent (v_1), Good (v_2), Middle (v_3), General (v_4) and Poor (v_5). Corresponding values are as follows: 0.80 above and 0.79~0.60, 0.59~0.50, 0.49~0.40, and under 0. 40. For different subsets of assessment, the meanings of the elements in the collection are not the same. To establish the assessment factors system structure diagram as shown in Figure 2. Evaluation factors is a subordinate relations associated class hierarchy, give class hierarchy is multistage evaluation factors system, and the top evaluation target. Here will be summarized as evaluation factors subset a secondary evaluation structure.



Level measurement set is:

$$U_1=\{u_1,u_2,u_3\}, \tag{4}$$

where u_1 task before you can carry effectiveness; u_2 to carry the main task effectiveness; u_3 is the carry the successor task effectiveness.

The second-level test set is a family of sets:

$$U_2=\{u_{1m_1},u_{2m_2},u_{3m_3}\}, \tag{5}$$

where $U_{im}=\{u_{i1},u_{i2},\cdots,u_{i3}\},i=1,2,3,$
$m_i=1,2,\cdots,M_i.$

By determining the parameters of the evaluation factors weight at all levels, come to the evaluation factors weight fuzzy membership vector parameters.

Level evaluation factors weight fuzzy sets as follows:

$$A_1=\{a_1,a_2,a_3\}. \tag{6}$$

Secondary fuzzy evaluation factors weight set is a family of sets:

$$A_2=\{A_{1m_1},A_{2m_2},A_{3m_3}\}, \tag{7}$$

where

$$A_{im}=\{a_{i1},a_{i2},\cdots,a_{im_i},a_{iM_i}\},i=1,2,3,\quad m_i=1,2,\cdots,M_i. \tag{8}$$

a_{im} of A_{im} is the evaluation factors in the fuzzy set membership.

According to the rating evaluation factors, first establish a mapping of each grade from *U* to *V*, establish distribution fuzzy to determine fuzzy relation matrix. Describe the evaluation factor in accurate mathematical

models through formulas to calculate values, later transformed into fuzzy fields within the membership. Using membership function finds the fuzzy relation matrix evaluation factor fuzzy relation matrix elements in r_{ij}.

The corresponding evaluation grade $v_i = \{j = 1, 2, 3, \cdots\}$. The degree of membership $a_{ij}(u_i)$ where $u_i = \{u = 1, 2, 3, \cdots\}$.

Based classification evaluation factors assessment for each grade of membership function is normal, its fuzzy distributed [7, 8]:

$$a_{ij}(u_i) = \exp\left[-\left(\frac{u_i - m_{ij}}{\delta_{ij}}\right)^2\right]. \quad (9)$$

Among them $a_{ij}(u_i)$, m_{ij} and δ_{ij}, respectively, for the first i evaluation factors on the first u_i, j, v_j the membership degree of evaluation grades and their statistical values of mean and variance

$$R_i = \begin{bmatrix} r_{i_{1\times1}} & r_{i_{2\times1}} & \cdots & r_{i_{1\times5}} \\ r_{i_{2\times1}} & r_{i_{2\times2}} & \cdots & r_{i_{2\times5}} \\ \vdots & \vdots & \vdots & \vdots \\ r_{i_{m\times1}} & r_{i_{m\times2}} & \cdots & r_{i_{m\times5}} \end{bmatrix}. \quad (10)$$

For model calculations, by determination of level measurement: $B = A \circ R = \{b_1, b_2, b_3, b_4, b_5\}$.

This operation model fuzzy operator for $M(\bullet, v)$: $B = A \circ R = \{b_1, b_2, b_3, b_4, b_5\}$.

Operations for the above levels in turn, calculated level of evaluation findings: $B = A \circ R = A_1 \circ (A_2 \circ A_1)$.

According to the principle of maximum membership degree judgment, their evaluation results are b corresponds to the maximum membership degree in evaluation of language [9].

4 Examples of application

Existing A, B, C three types of weapons and equipment combat system, according to the requirements of the soldiers of equipment capability, intends to select fire damage ability, field survival ability, mobility; the adaptability of battlefield four aspects of the comprehensive ability inspects the comprehensive performance of the combat system equipment.

TABLE 1 the performance of the three types of weapons and equipment combat system technical index

Capacity indicator	Performance indicators	Type series		
		Model A	Model B	Model C
Fire damage	Ammunition power	Excellent (0.75)	Excellent (0.75)	Good (0.625)
	Range	Excellent (0.75)	Excellent (0.75)	Excellent (0.75)
	Precision	Medium (0.50)	Medium (0.50)	Good (0.625)
	Measure aiming at the response time	Medium (0.50)	Excellent (0.75)	Good (0.625)
	Fire duration	Medium (0.50)	Medium (0.50)	Medium (0.50)
Battlefield survivability	Camouflage ability	Good (0.625)	Medium (0.50)	Medium (0.50)
	Protection capability	Good (0.625)	Excellent (0.75)	Good (0.625)
	Risk perception	Medium (0.50)	Good (0.625)	Medium (0.50)
	Work time	Good (0.625)	Medium (0.50)	Good (0.625)
Mobility	total weight	Good (0.625)	Excellent (0.75)	Medium (0.50)
	Overall dimensions	Medium (0.50)	Medium (0.50)	Medium (0.50)
	Time to prepare	Good (0.625)	Medium (0.50)	Good (0.625)
Battlefield adaptability	reliability	Poor (0.25)	Medium (0.50)	Medium (0.50)
	availability	Medium (0.50)	Medium (0.50)	Medium (0.50)
	Service features	Medium (0.50)	Good (0.625)	Poor (0.25)

The influence factors of the efficiency evaluation set up $V = \{v_1, v_2, v_3, v_4, v_5\}$, including v_1, v_2, v_3, v_4, v_5 respectively corresponding to the excellent, good, good, medium and poor. The values above 1.0, 0.75, 0.625, 0.75 and 0.625 below, (ex: as shown in Table 1).

Using analytic methods, determining each factor index on the upper level index weighting is as follows:

$w = (0.428, 0.160, 0.128, 0.074)$,

$w_1 = (0.458, 0.041, 0.162, 0.256)$,

$w_2 = (0.053, 0.548, 0.102, 0.297)$,

$w_3 = (0.731, 0.081, 0.188)$,

$w_4 = (0.637, 0.258, 0.105)$.

4.1 INTEGRATED PERFORMANCE INDICATOR LEVEL OF EVALUATION

Table 1 performance of weapon equipment operational systems in fire damage capability properties matrix is:

$$R_1 = \begin{bmatrix} 0.75 & 0.75 & 0.625 \\ 0.75 & 0.75 & 0.75 \\ 0.50 & 0.50 & 0.625 \\ 0.50 & 0.75 & 0.625 \\ 0.50 & 0.50 & 0.50 \end{bmatrix}.$$

A planning is: $R_1 = \begin{bmatrix} 1 & 1 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0.5 \\ 0 & 0 & 0 \end{bmatrix}.$

The optimal vector $G_1 = (1,0,1,1,0)$, $B_1 = (0,0,0,0,0)$, known weight vector for $w_1 = (0.458, 0.041, 0.162, 0.256)$ can be calculated for each vector-valued, generation into the evaluation model, the evaluation results will be achieved.

$$u_1 = \{0.6490, 0.8349, 0.2247\}.$$

Similarly, it can be obtained:

$$u_2 = \{0.2462, 0.7538, 0.1752\},$$

$$u_3 = \{0.8228, 0.8795, 0.1205\},$$

$$u_4 = \{0.1008, 0.9208, 0.8396\}.$$

4.2 COMPREHENSIVE PERFORMANCE INDEX OF THE SECONDARY EVALUATION

$$R_1 = \begin{bmatrix} 0.6490 & 0.8349 & 0.2447 \\ 0.2462 & 0.7538 & 0.1752 \\ 0.8228 & 0.8795 & 0.1205 \\ 0.1008 & 0.9208 & 0.8396 \end{bmatrix}.$$

The optimal vector $G = (0.8349, 0.7538, 0.8795, 0.9208)$, $B = (0.2247, 0.1752, 0.1205, 0.1008)$, known weight vector for $w = (0.428, 0.160, 0.128, 0.074)$ can be calculated for each vector-valued, generation into the evaluation model, the evaluation results will be achieved: $u = \{0.1670, 0.9783, 0.0458\}$.

4.3 EXPERIMENTAL EVALUATION OF THE RESULTS

Through the above evaluation results of the comparison, from the size of the comprehensive performance, A model > B model > C model, the in conformity with the actual situation is. Compared with other comprehensive performance evaluation method, the result is reasonable, more practicable methods.

5 Conclusions

Weapons in combat role in the process of weapon equipment can be used in the process of operations in ability to measure stipulated task. Combat system effectiveness evaluation is one of the most important evaluation indexes of weapon equipment system; it can reflect the essence of weapon system. Using fuzzy comprehensive evaluation method, through the establishment of weapons and equipment combat system evaluation model, can be found by the experimental results on the efficiency of weapon equipment operational system qualitative quantitative research. Give full play to command and combat effectiveness, to make the equipment system effectiveness is stronger than the enemy.

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