Joint Operation Scheme Evaluation Based on Uncertain Language Multi-Attribute Decision-Making

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Abstract: In order to improve the quality and efficiency of joint operation scheme evaluation, a joint operation scheme evaluation model based on uncertain language multi-attribute decision-making is proposed. In this paper, the basic process of joint operation scheme preparation is summarized, and the multi-attribute system of joint operation scheme is taken as the evaluation index, and the uncertain language evaluation method of each attribute is given. The UEWAA operator is used to optimize and rank the joint operation plans, and the commander determines the final operation plan. The weighted vector of UEWAA operator can be adjusted and determined by commanders and assessors in time according to specific combat tasks and situations, which improves the flexibility and applicability of the evaluation algorithm.

1. Introduction

As a product of joint operation mission planning, joint operation scheme is the overall design of combat task, operation process, force utilization and action tactics according to joint operation intention. Its essence is the strategy collection of implementing joint operation and the basis of action command. Compared with the operational plan focusing on specific implementation, the operational scheme focuses on stratagems. The preparation of operation scheme has strong strategy, and the language is relatively rough and fuzzy, most of which are qualitative and abstract words.it is necessary to make a comprehensive evaluation of the joint operation scheme according to different operational purposes, so as to select the optimal scheme. The evaluation of joint operation scheme is the key link of joint operation mission planning, its purpose is to provide basis and conditions for optimizing and improving the operation scheme. Since the right of final decision of the operational scheme is in the commander's hand, the commander's "preference" can be used as the basis for evaluating the weight of the index, which can better take into account all aspects of the scheme.

In reference [1], a evaluation method of joint operation scheme based on multi-objective fuzzy decision-making is proposed according to the qualitative criteria and the quantitative mathematical model. In reference [2], a comprehensive evaluation method of operational scheme based on fuzzy comprehensive evaluation and combat simulation is proposed. The method evaluates the core elements of the operation scheme by static operational research analysis, and evaluates the effect of combat action by dynamic simulation. In reference [3], an evaluation method of joint operation scheme based on genetic neural network is proposed. Its basic principle is to learn and train the known operation scheme samples through the network and recognize the new samples. In reference [4], basic steps of operation scheme evaluation based on simulation and the logic module supporting the evaluation are given according to the steps of command and decision making, and the static evaluation index system is established. Based on the analysis of uncertain linguistic evaluation of joint operation scheme, the optimal weight of each attribute is determined by the distance between the commander's preference value and attribute value, and the multi-attribute decision-making method of uncertain language is used to evaluate and optimize the operation scheme, so as to improve the quality and efficiency of joint operation scheme evaluation.

2. Uncertain language variables of joint operation scheme evaluation

2.1 Formulation of joint operation scheme

With the rapid improvement of human decision-making ability and the military decision-making target is becoming more and more complex, the amount of information processed in the decision-making is increasing day by day. Joint operation is a complex system confrontation based on network information system, which involves a wide range of operations, a great time span, many elements and strong correlation, which brings about the complexity and uncertainty of joint operation decision-making environment.

The operation scheme is usually generated in the form of "text & chart", relying on the operational command information system to form standardized results. A large amount of intelligence data, condition data and operational data are usually used as the basis to draw up operational scheme. This puts forward new requirements for the construction of operational database and data classification and extraction technology. The preparation process of joint operation scheme is shown in Figure 1.

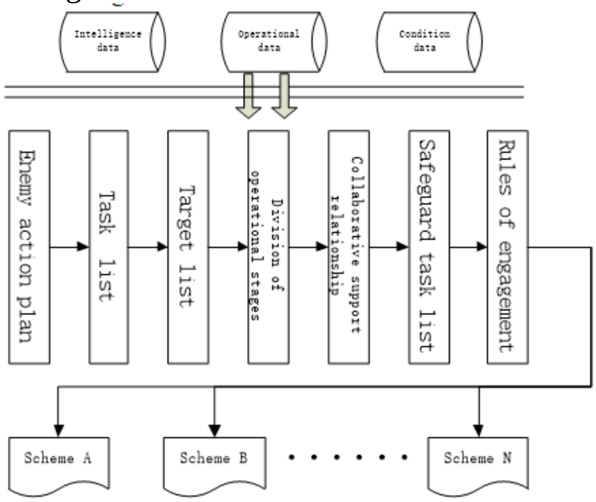

Figure 1 preparation process of joint operation scheme

Evaluators usually participate in the preparation of multiple schemes before evaluating joint them. There are differences in the tactics and the use of strength among the various schemes, so as to facilitate commander to select and make decisions. In the evaluation of operational scheme, the evaluation organization integrates the basic data, operational scenario data, operational composition data, equipment performance data, combat target data, battlefield environment data, laws and regulations standards and military rules to support the establishment of operational models, engagement rules and evaluation standards.

2.2 Uncertain language variable of joint operation scheme

Due to the complexity of joint operations, preference information, such as natural language, uncertain language or multi granularity language, is often used to describe the situation, judgment conclusion, combat task, combat intention, force application, operation method etc.[9] which conforms to the fuzziness of human thinking, which is conducive to the commander to grasp the operation process and reduce the commander's pressure and improve the efficiency of decision-making. The operation scheme has different evaluation indexes, such as purposefulness, feasibility, coordination, risk, flexibility, etc. Commanders can only give fuzzy evaluation of each attribute based on experience, such as "Scheme I has strong operational capability satisfaction", "scheme II has poor implementation effectiveness". This leads to the uncertainty of operation scheme evaluation indexes[9].

Uncertain language variable is defined as:

Definition 1[10] If $\tilde{\mu} = [s_a, s_b]$, $s_a, s_b \in \tilde{S}$, s_a and s_b is the lower limit and the upper limit of $\tilde{\mu}$,then the $\tilde{\mu}$ is an uncertain language variable.

2.3 Value of commander's preference

In the activities of scheme evaluation , the commander will sort each scheme in the scheme-set in advance, and the commander's preference for each scheme is affected by his own quality and decision-making style, resulting in the deviation between the "overall preference" of the scheme and the "individual preference" of the attributes, which is called the deviation between the commander's preference value and the attribute value. For example, some commanders are more concerned about the "timeliness of scheme formulation" so that they highly evaluate it. But the scheme may not be able to complete the mission well in the overall situation. In order to make the evaluation more reasonable, the weight of each attribute should be determined to minimize the distances between the commander's preference value and each attribute value.

3. Joint operation scheme evaluation

3.1 Multi-attribute decision-making

Multiple-attribute decision-making (MADM) refers to a process in which each scheme is comprehensively sorted and optimized from several attributes under a given set of finite number of schemes.

3.2 Evaluation index system of joint operation scheme

Task adaptability, execution effectiveness and content applicability are the main decision-making indexes that affect the evaluation of joint operation scheme. Task adaptability is mainly determined by operational intention, combat task, combat capability of force and adaptability of battlefield environment. Execution effectiveness refers to implementation progress of scheme, realization degree of operational purpose, expected combat effect and expected risk and cost; Content applicability refers to whether resources such as strength, time and space required to complete tasks are available and whether they are adapt to the changes of various situations effectively. As it shown in Figure 2.

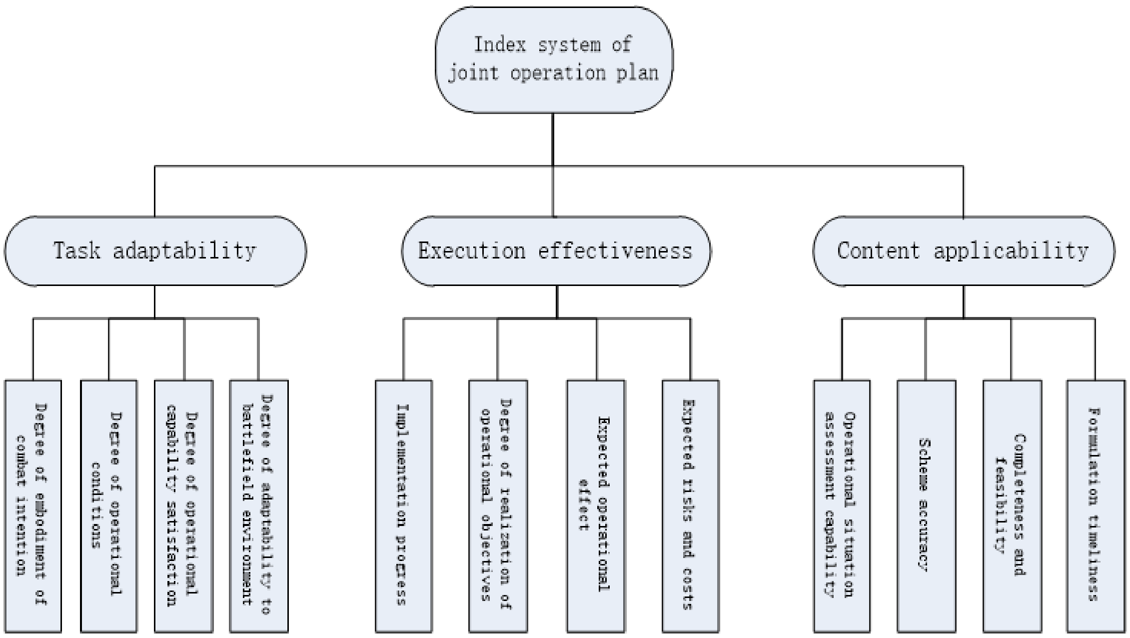

Figure 2 Multi-attribute system of joint operation scheme

3.3 Multi-attribute decision-making process of joint operation scheme evaluation

Considering that the operation scheme is affected by the comprehensive evaluation indexes and the weight is obvious, UEWAA operator is a multiplicative and bounded operator, which can ensure that the weight and the information of each evaluation matrix can be fully utilized, and the scheme comprehensiveness can be effectively considered. It is an optimization operator suitable for the comprehensive evaluation of joint operation scheme. It is defined as:

Definition 2[7] If $\tilde{\mu} = [s_a, s_b], \tilde{\upsilon} = [s_c, s_d] \in \tilde{S}, l_{ab} = b - a, l_{cd} = d - c$, then the degree of possibility of $\tilde{\mu} \geq \tilde{\upsilon}$ is defined as follows :

$$p(\tilde{\mu} \geq \tilde{\upsilon}) = max\left\{1 - max\left(\frac{d-a}{l_{ab}+l_{cd}}, 0\right), 0\right\} \quad (1)$$

Definition 3[7] If

$$\mathrm{UEWAA}_w = (w_1\tilde{\upsilon}_1 \oplus w_2\tilde{\upsilon}_2 \oplus \ldots \oplus w_n\tilde{\upsilon}_n).$$

Among which, $w = (w_1, w_2, \ldots, w_n)$ is the weighted vector of uncertain language variable $\tilde{\upsilon}_i$, $w_i \in [0,1](i \in N)$,then the UEWAA operator is said to be an uncertain EWAA operator.

Definition 4[7] If $\tilde{\mu} = [s_a, s_b], \tilde{\upsilon} = [s_c, s_d] \in \tilde{S}$, then the deviation between $\tilde{\mu}$ and $\tilde{\upsilon}$ is :

$$d(\tilde{\mu}, \tilde{\upsilon}) = |s_b - s_d| + |s_a - s_c| \quad (2)$$

The method of weight calculation based on the distances between the commander's preference value and each attribute value is given as follows: [7]

$$\mathrm{w_j} = \frac{\sum_{i=1}^{m}[d^2(\tilde{r}_{ij}, \tilde{\theta}_i)]}{\sum_{j=1}^{n}\{\sum_{i=1}^{m}[d^2(\tilde{r}_{ij}, \tilde{\theta}_i)]^{-1}\}} \quad (3)$$

where:$d(\tilde{r}_{ij}, \tilde{\theta}_i)$ is the deviation between the commander's preference value $\tilde{\theta}_i$ and the attribute value r_{ij}.

The ordering vector $k = (k_1, k_2, \ldots, k_n)$ of the possibility matrix is obtained by formula (4):

$$k_i = \frac{1}{n(n-1)}\left[\sum_{j=1}^{n} a_{ij} + \frac{n}{2} - 1\right], i \in N \quad (4)$$

The multi-attribute decision-making method is proposed as shown in Figure 3.

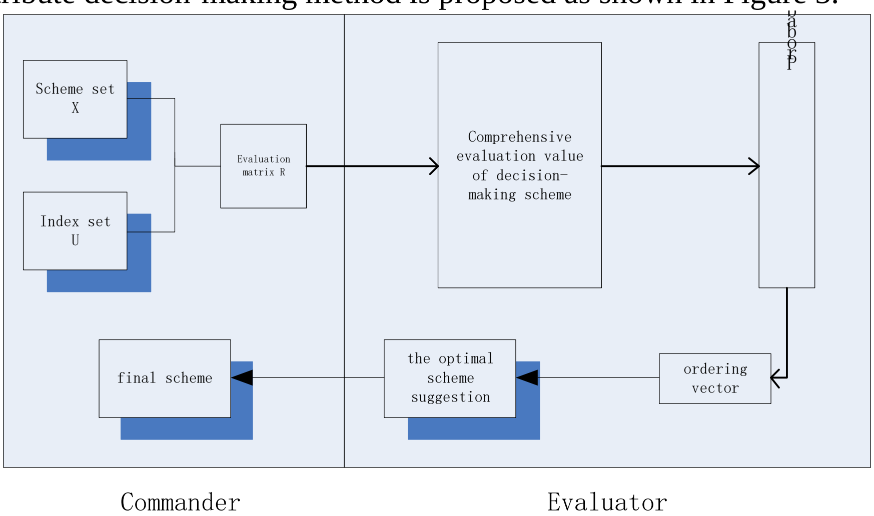

Figure 3 Steps of multi-attribute decision-making method based on UEWAA operator

4. Case Analysis

Taking the counterattack operation of a campaign group army as an example, and taking the combat troops and degree of space information support as the control variables, according to the specific battlefield environment, multiple sets of joint operation schemes are formed.

(1) Formulate the joint operations plan set

Four plans were formulated with the operational command information system: $x_i(i = 1,2,3,4)$. Among them, main differences of each scheme are as follows:

x_1:The main counterattack forces are motorized infantry brigade and armored brigades with no space information support;

x_2:The main counterattack forces are motorized infantry brigade and border defence corps with no space information support;

x_3:The main counterattack forces are motorized infantry brigade and armored brigades with space information support;

x_4:The main counterattack forces are motorized infantry brigade and border defence corps with space information support.

(2) Establish attribute set of joint operation scheme

Select the degree of embodiment of operational intention(u_1), the degree of operational conditions(u_2), the degree of operational capability(u_3),the degree of Battlefield adaptation(u_4),Expected operational effect(u_5),Expected risks and costs(u_6),Operational situation assessment capability(u_7),the integrality and feasibility of scheme(u_8) as the evaluation basis from Figure 2.

(3) Establishment of uncertain language evaluation scale

The uncertain language evaluation of each attribute is listed according to the actual situation. The evaluation scale is:$S = \{s_{-5}, s_{-4}, \dots, s_4, s_5\}$[10],This scale division can overcome the inaccuracy of risk rating scale [8].

(4) The UEWAA operator is used to evaluate. The specific steps are as follows:

Firstly, the evaluation matrix is established

Table. 1 Evaluation matrix $\tilde{R}$

	x_1	x_2	x_3	x_4
u_1	$[s_0, s_2]$	$[s_1, s_2]$	$[s_0, s_2]$	$[s_1, s_2]$
u_2	$[s_2, s_3]$	$[s_0, s_1]$	$[s_3, s_4]$	$[s_2, s_3]$
u_3	$[s_2, s_4]$	$[s_{-2}, s_0]$	$[s_3, s_5]$	$[s_{-1}, s_1]$
u_4	$[s_{-4}, s_{-2}]$	$[s_2, s_4]$	$[s_{-4}, s_{-2}]$	$[s_3, s_5]$
u_5	$[s_2, s_3]$	$[s_{-1}, s_0]$	$[s_3, s_4]$	$[s_0, s_2]$
u_6	$[s_{-2}, s_{-1}]$	$[s_{-4}, s_{-2}]$	$[s_{-1}, s_0]$	$[s_{-3}, s_{-1}]$
u_7	$[s_1, s_2]$	$[s_2, s_3]$	$[s_3, s_5]$	$[s_4, s_5]$
u_8	$[s_1, s_3]$	$[s_2, s_3]$	$[s_3, s_4]$	$[s_2, s_3]$

Then the synthetic attribute evaluation values $\tilde{z}_i(w)(i \in N)$ of decision scheme x_i is calculated.

Assume that the commander's preference value for the four schemes is:

$$\tilde{\theta}_1 = [1,3], \tilde{\theta}_2 = [2,3], \tilde{\theta}_3 = [2,3], \tilde{\theta}_4 = [2,4]$$

The weighted vector of UEWAA operator is calculated by using formula (2) and (3):

$$w = (0.08\ 0.08\ 0.15\ 0.20\ 0.11\ 0.29\ 0.06\ 0.03)$$

Aggregation using UEWAA operator:

$$\tilde{z}_1(w) = 0.08 \times [s_0, s_2] \oplus 0.08 \times [s_2, s_3] \oplus 0.15 \times [s_2, s_4] \oplus 0.20 \times [s_{-4}, s_{-2}] \oplus 0.11 \times [s_2, s_3] \oplus 0.29 \times [s_{-2}, s_{-1}] \oplus 0.06 \times [s_1, s_2] \oplus 0.03 \times [s_1, s_3] = [s_{-0.61}, s_{0.67}]$$

$$\tilde{z}_2(w) = 0.08 \times [s_1, s_2] \oplus 0.08 \times [s_0, s_1] \oplus 0.15 \times [s_{-2}, s_0] \oplus 0.20 \times [s_2, s_4] \oplus 0.11 \times [s_{-1}, s_0] \oplus 0.29 \times [s_{-4}, s_{-2}] \oplus 0.06 \times [s_2, s_3] \oplus 0.03 \times [s_2, s_3] = [s_{-0.91}, s_{1.19}]$$

$$\tilde{z}_3(w) = 0.08 \times [s_0, s_2] \oplus 0.08 \times [s_3, s_4] \oplus 0.15 \times [s_3, s_5] \oplus 0.20 \times [s_{-4}, s_{-2}] \oplus 0.11 \times [s_3, s_4] \oplus 0.29 \times [s_{-1}, s_0] \oplus 0.06 \times [s_3, s_5] \oplus 0.03 \times [s_3, s_4] = [s_{0.20}, s_{1.39}]$$

$$\tilde{z}_4(w) = 0.08 \times [s_1, s_2] \oplus 0.8 \times [s_2, s_3] \oplus 0.15 \times [s_{-1}, s_1] \oplus 0.20 \times [s_3, s_5] \oplus 0.11 \times [s_0, s_2] \oplus 0.29 \times [s_{-3}, s_{-1}] \oplus 0.06 \times [s_4, s_5] \oplus 0.03 \times [s_2, s_3] = [s_{0.20}, s_{0.97}]$$

Calculate the probability($a_{ij} = p\left(\tilde{z}_i(w) \geq \tilde{z}_j(w)\right)(i, j \in N)$) of composite attribute value $\tilde{z}_i(w)(i \in N)$ among each scheme, the probability degree complementarity matrix is established.

$$\mathbf{A}=\begin{bmatrix} 0.5 & 0.4675 & 0.1903 & 0.2293 \\ 0.5325 & 0.5 & 0.6991 & 0.3449 \\ 0.8097 & 0.3009 & 0.5 & 0.6071 \\ 0.7707 & 0.6551 & 0.3929 & 0.5 \end{bmatrix}$$

Finally, formula (4) is used to calculate the ordering vector of probability degree matrix **A**:

$$k=(0.1992,0.2564,0.2681,0.2766)$$

Sort the 4 schemes:$x_4 > x_3 > x_2 > x_1$.

According to the ranking results, the optimal scheme is $\boldsymbol{x_4}$. From a practical point of view, under the constraints of certain operational conditions and battlefield environment, the satisfaction degree to combat ability of scheme $\boldsymbol{x_1}$ is higher than scheme $\boldsymbol{x_2}$, But the battlefield environment was poorly adapted. For example, in some border areas, where armored forces cannot be deployed, the overall operational efficiency is poor. After joining the space information support force, the scheme has significantly improved the combat situation research and judgment ability, thus greatly improving the overall combat capability of the force, basically reflecting the actual situation of the operation.

5. Conclusion

The formulation of joint operation scheme should involve the deep participation of commanders and evaluators, so that the joint operation scheme has relative dynamic adaptability, which is the development direction of intelligent combat mission planning system. Combined with the experience of commanders and evaluators, the evaluation of joint operation scheme based on uncertain language multi-attribute decision-making is selected from the existing operational data, and the evaluators participate in the whole process of scheme preparation. For multiple operational scheme, Commanders and evaluators are based on their experience and actual troop conditions to calculate the weight of each attribute by the distances between the commander's preference value and each attribute value, the evaluation and sequencing of each scheme will provide the basis for the commander to select the final scheme.

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