# Research on Optimization of Equipment Operation Scheme Based on AHP Fuzzy Comprehensive Evaluation Method

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**Abstract.** With the increase of multi-purpose equipment, how to determine the equipment application scheme is an important problem. Aiming at the optimization of equipment application scheme, this paper adopts the scheme optimization method based on AHP fuzzy comprehensive evaluation method. In this method, AHP method is used to distribute the weight of each evaluation index. On this basis, fuzzy comprehensive evaluation method is used to comprehensively evaluate the equipment application scheme, and finally the optimal design scheme is obtained. By applying this method to the evaluation of a certain type of equipment application scheme, the effectiveness of the method is verified. This method organically combines quantitative analysis and qualitative analysis, and requires less quantitative data information in the evaluation process. It can effectively solve the multi-level and multi-objective large-scale system optimization problem.

**Keywords:** AHP, Fuzzy Comprehensive Evaluation method, Unmanned equipment, equipment operation scheme.

## 1. AHP fuzzy comprehensive evaluation method

AHP systematizes, models and mathematicizes the decision-making thinking process of complex objects. It is an effective analysis tool for multi criteria and multi-objective decision-making problems with complex structure. AHP is very suitable for the early stage of decision-making. Its basic idea reflects the basic characteristics of people's decision-making thinking: decomposition judgment synthesis. Generally, the basic steps of solving problems by analytic hierarchy process are [3]: establishing problem hierarchy, constructing comparison judgment matrix, consistency test and hierarchical ranking. AHP generally divides the problem into: the highest level, the middle level and the lowest level. The highest level is often the target level of the problem, which is the purpose of solving the problem; The middle layer can be different criteria, measures and schemes for the target, indicating the intermediate link to solve the target problem; At the bottom are some specific measures to solve the problem, which are the actual indicators, performance and methods to solve the problem related to the criteria of the middle layer. The number of middle layers of analytic hierarchy process will vary according to different actual problems. There are more steps to solve more complex problems, and there will be more corresponding middle layers. The structural model of analytic hierarchy process is shown in Fig. 1.

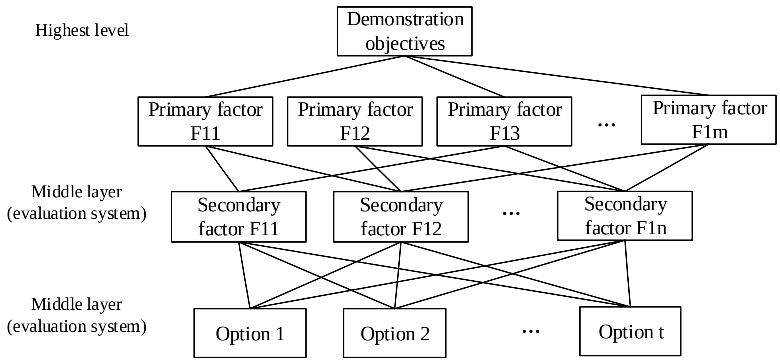


**Figure 1.** Hierarchy of AHP

Fuzzy comprehensive evaluation method is a specific application method of fuzzy mathematics. It can express all kinds of uncertain information with quantitative methods, and then get the evaluation result matrix with the help of fuzzy operation. Through the evaluation result matrix, we can not only get the evaluation grade of the evaluation object, but also get the specific situation of each grade and other useful information. At present, it is widely used in many fields.

AHP fuzzy comprehensive evaluation method is a comprehensive evaluation method based on fuzzy set theory, applying the principle of fuzzy relationship synthesis and using analytic hierarchy process theory to analyze the level of multiple factors. Its basic steps are as follows:

(1) Determine the factor set of the evaluation object. Factor set is a set of elements composed of various factors affecting the evaluation object, which is usually represented by U: $U=\{u_1, u_2, \cdots, u_n\}$, that is to determine the evaluation index system and solve the problem of what index to use and from which aspects to evaluate the objective object.

(2) Establish evaluation set. It is a set composed of various evaluation results that the evaluator may make on the evaluation indicators, that is, a set indicating the advantages and disadvantages of the evaluation objectives. The set of comments is set as $V=\{V_1, V_2, \cdots, V_m\}$. Because the evaluation set is a set composed of various possible results of the total evaluation as elements, there is only one evaluation set no matter how many categories the factors are divided into.

(3) Establish the weight distribution vector of evaluation factors. Each factor in the evaluation factor set has a different position in the "evaluation objective", that is, each evaluation factor occupies a different proportion in the comprehensive evaluation. This proportion is called the weight. There are many methods to determine the weight. Analytic hierarchy process is used in this paper. In order to simplify the calculation, the analytic hierarchy process adopts an approximate method, the square root method.

(4) Carry out single factor evaluation and establish fuzzy relationship matrix. A comprehensive evaluation matrix shall be established for each evaluation object, $R_i=(r_{i1}, r_{i2}, \cdots, r_{in})$ is the single factor evaluation of the ith factor, $r_{ij}$ is the frequency distribution, and it is generally normalized to meet $\sum_{j=1}^{n} r_{ij}=1$.

(5) Carry out compound operation to obtain comprehensive evaluation results:

$$\underline{B}=\underline{A}\cdot \underline{R}=\{b_1, b_2, \cdots, b_N\}$$

## 2. Evaluation process of unmanned equipment application scheme

Unmanned equipment is a general concept and a general term for all equipment without driving. In the future, due to the advantages of high efficiency and low cost, unmanned equipment can overcome the adverse effects of climatic conditions and implement all-weather operation, which will occupy an important position in the society. Taking the optimization of an unmanned equipment application scheme as an example, this paper evaluates and selects the scheme by using AHP fuzzy comprehensive evaluation method, obtains the optimal result, and verifies the feasibility of this method.

The schemes to be optimized in this paper mainly include: aerial broadcasting, aerial Boeing, power grid maintenance, disaster rescue, aerial photography and air transportation (schemes a, B, C, D, e and f respectively). In order to evaluate the advantages and disadvantages of these schemes, we will use the above evaluation method for evaluation. During the evaluation, we invited 10 experts to form an expert group to review the scheme. The specific evaluation steps are as follows:

### 2.1. Determine the factor set of the evaluation object

Establish evaluation factor set u, that is, select the set of evaluation indicators. The basic factor set u is divided into n subsets according to the types of some attributes, which can be recorded as, so as to establish a complete evaluation factor index system that can reflect the evaluation level. For the evaluation index system of unmanned equipment operation scheme, the evaluation index is divided into two levels, the first level is divided into five subsets, and the second level is divided into 15 subsets. Therefore, the evaluation factor set and factor subset of unmanned equipment operation scheme are determined as follows:

$U = \{U_1, U_2, U_3, U_4, U_5\}$={functional index, technical index, economic index, safety index, manufacturability index};

$U_1 = \{U_{11}, U_{12}, U_{13}\}$={operation time, operation range, operation speed};

$U_2 = \{U_{21}, U_{22}, U_{23}\}$={maneuverability, braking performance, control convenience};

$U_3 = \{U_{31}, U_{32}, U_{33}\}$={energy consumption level, material price, maintainability};

$U_4 = \{U_{41}, U_{42}, U_{43}\}$={balance ability, anti-collision ability, self rescue ability};

$U_5 = \{U_{51}, U_{52}, U_{53}\}$={assemblability, progress control level, structural manufacturability}.

## 2.2. Establish evaluation set

Evaluation set is a set composed of various evaluation results that evaluators may make on evaluation indicators, that is, a set indicating the advantages and disadvantages of evaluation objectives. In the evaluation of this scheme, we adopt 4-level evaluation, that is, v = {very good, good, average, poor}. The specific score of each comment set is given by relevant experts, and the ten point system is used to distinguish. By inviting experts to score the six schemes A-F, we get the following six fuzzy matrices after calculation:

$$U_A = \begin{bmatrix} 0.1 & 0.1 & 0.3 & 0.5 \\ 0.0 & 0.0 & 0.4 & 0.6 \\ 0.0 & 0.0 & 0.2 & 0.8 \\ 0.4 & 0.3 & 0.2 & 0.1 \\ 0.5 & 0.3 & 0.2 & 0.0 \\ 0.5 & 0.4 & 0.1 & 0.0 \\ 0.1 & 0.4 & 0.4 & 0.1 \\ 0.5 & 0.4 & 0.1 & 0.0 \\ 0.5 & 0.4 & 0.1 & 0.0 \\ 0.3 & 0.4 & 0.2 & 0.1 \\ 0.5 & 0.4 & 0.1 & 0.0 \\ 0.4 & 0.4 & 0.2 & 0.0 \\ 0.2 & 0.4 & 0.4 & 0.0 \\ 0.5 & 0.4 & 0.1 & 0.0 \\ 0.3 & 0.4 & 0.2 & 0.1 \end{bmatrix} U_B = \begin{bmatrix} 0.0 & 0.2 & 0.3 & 0.5 \\ 0.2 & 0.4 & 0.4 & 0.0 \\ 0.1 & 0.3 & 0.4 & 0.2 \\ 0.1 & 0.4 & 0.3 & 0.2 \\ 0.0 & 0.2 & 0.4 & 0.4 \\ 0.1 & 0.4 & 0.4 & 0.1 \\ 0.1 & 0.4 & 0.4 & 0.1 \\ 0.1 & 0.3 & 0.4 & 0.2 \\ 0.3 & 0.3 & 0.4 & 0.0 \\ 0.0 & 0.2 & 0.4 & 0.4 \\ 0.0 & 0.2 & 0.4 & 0.4 \\ 0.0 & 0.2 & 0.4 & 0.4 \\ 0.0 & 0.2 & 0.5 & 0.3 \\ 0.0 & 0.2 & 0.3 & 0.5 \\ 0.1 & 0.2 & 0.3 & 0.4 \end{bmatrix} U_C = \begin{bmatrix} 0.0 & 0.1 & 0.4 & 0.5 \\ 0.1 & 0.2 & 0.4 & 0.3 \\ 0.0 & 0.2 & 0.3 & 0.5 \\ 0.0 & 0.2 & 0.4 & 0.4 \\ 0.0 & 0.1 & 0.5 & 0.4 \\ 0.0 & 0.1 & 0.4 & 0.5 \\ 0.0 & 0.2 & 0.4 & 0.4 \\ 0.0 & 0.3 & 0.4 & 0.3 \\ 0.0 & 0.2 & 0.4 & 0.4 \\ 0.1 & 0.2 & 0.4 & 0.3 \\ 0.1 & 0.2 & 0.4 & 0.3 \\ 0.0 & 0.0 & 0.1 & 0.9 \\ 0.0 & 0.1 & 0.5 & 0.4 \\ 0.0 & 0.1 & 0.5 & 0.4 \\ 0.0 & 0.1 & 0.5 & 0.4 \end{bmatrix} U_D = \begin{bmatrix} 0.1 & 0.3 & 0.5 & 0.1 \\ 0.2 & 0.2 & 0.4 & 0.2 \\ 0.1 & 0.2 & 0.4 & 0.3 \\ 0.1 & 0.3 & 0.4 & 0.2 \\ 0.0 & 0.3 & 0.3 & 0.4 \\ 0.1 & 0.3 & 0.4 & 0.2 \\ 0.0 & 0.2 & 0.4 & 0.4 \\ 0.2 & 0.3 & 0.5 & 0.0 \\ 0.1 & 0.3 & 0.5 & 0.1 \\ 0.2 & 0.3 & 0.4 & 0.1 \\ 0.2 & 0.3 & 0.4 & 0.1 \\ 0.0 & 0.0 & 0.4 & 0.6 \\ 0.2 & 0.4 & 0.4 & 0.0 \\ 0.2 & 0.5 & 0.2 & 0.1 \\ 0.2 & 0.5 & 0.2 & 0.1 \end{bmatrix} U_E = \begin{bmatrix} 0.1 & 0.4 & 0.5 & 0.0 \\ 0.3 & 0.5 & 0.2 & 0.0 \\ 0.2 & 0.4 & 0.3 & 0.1 \\ 0.2 & 0.4 & 0.3 & 0.1 \\ 0.0 & 0.3 & 0.4 & 0.3 \\ 0.2 & 0.4 & 0.3 & 0.1 \\ 0.1 & 0.1 & 0.4 & 0.4 \\ 0.0 & 0.2 & 0.5 & 0.3 \\ 0.0 & 0.2 & 0.5 & 0.3 \\ 0.2 & 0.4 & 0.3 & 0.1 \\ 0.2 & 0.4 & 0.3 & 0.1 \\ 0.0 & 0.2 & 0.4 & 0.4 \\ 0.0 & 0.4 & 0.3 & 0.1 \\ 0.0 & 0.2 & 0.3 & 0.5 \\ 0.1 & 0.4 & 0.3 & 0.2 \end{bmatrix} U_F = \begin{bmatrix} 0.0 & 0.1 & 0.5 & 0.4 \\ 0.0 & 0.4 & 0.4 & 0.2 \\ 0.1 & 0.2 & 0.5 & 0.2 \\ 0.0 & 0.3 & 0.5 & 0.2 \\ 0.0 & 0.1 & 0.5 & 0.4 \\ 0.0 & 0.3 & 0.5 & 0.2 \\ 0.0 & 0.2 & 0.5 & 0.3 \\ 0.0 & 0.1 & 0.3 & 0.6 \\ 0.0 & 0.1 & 0.3 & 0.6 \\ 0.0 & 0.3 & 0.4 & 0.3 \\ 0.0 & 0.3 & 0.4 & 0.3 \\ 0.0 & 0.1 & 0.4 & 0.5 \\ 0.0 & 0.0 & 0.2 & 0.8 \\ 0.0 & 0.0 & 0.4 & 0.6 \\ 0.0 & 0.1 & 0.4 & 0.5 \end{bmatrix}$$

## 2.3. Determine the weight of each factor

The weight of each factor of unmanned equipment can be obtained by analytic hierarchy process. The calculation results of primary and secondary indicators are shown in Table 1, Table 2, Table 3, Table 4, Table 5 and Table 6.

**Table 1.** Comparison of importance of primary indicators

| U | U1 | U2 | U3 | U4 | U5 | W | Consistency test |
|---|---|---|---|---|---|---|---|
| U1 | 1 | 3 | 5 | 2 | 7 | 0.4455 | |
| U2 | 1/3 | 1 | 2 | 1/2 | 5 | 0.1741 | |
| U3 | 1/5 | 1/2 | 1 | 1/2 | 3 | 0.1057 | CR=0.0345<0.10 |
| U4 | 1/2 | 2 | 2 | 1 | 3 | 0.2245 | |
| U5 | 1/7 | 1/5 | 1/3 | 1/3 | 1 | 0.0502 | |

**Table 2.** Comparison of importance of functional indicators

| U1 | U11 | U12 | U13 | W1 | Consistency test |
|---|---|---|---|---|---|
| U11 | 1 | 1/5 | 1/3 | 0.1095 | |
| U12 | 5 | 1 | 2 | 0.5816 | CR=0.0032<0.10 |
| U13 | 3 | 1/2 | 1 | 0.3090 | |

**Table 3.** Comparison of importance of technical indicators

| U2 | U21 | U22 | U23 | W2 | Consistency test |
|---|---|---|---|---|---|
| U21 | 1 | 1/2 | 3 | 0.3090 | |
| U22 | 2 | 1 | 5 | 0.5816 | CR=0.0032<0.10 |
| U23 | 1/3 | 1/5 | 1 | 0.1095 | |

**Table 4.** Comparison of importance of economic indicators

| U3 | U31 | U32 | U33 | W3 | Consistency test |
|---|---|---|---|---|---|
| U31 | 1 | 1/2 | 1/5 | 0.1220 | CR=0.0032<0.10 |
| U32 | 2 | 1 | 1/3 | 0.2297 | |
| U33 | 5 | 3 | 1 | 0.6483 | |

**Table 5.** Comparison of importance of safety indicators

| U4 | U41 | U42 | U43 | W4 | Consistency test |
|---|---|---|---|---|---|
| U41 | 1 | 3 | 1/3 | 0.2583 | CR=0.0332<0.10 |
| U42 | 1/3 | 1 | 1/5 | 0.1047 | |
| U43 | 3 | 5 | 1 | 0.6370 | |

**Table 6.** Importance comparison of manufacturable index

| U5 | U51 | U52 | U53 | W5 | Consistency test |
|---|---|---|---|---|---|
| U51 | 1 | 3 | 2 | 0.5396 | CR=0.0079<0.10 |
| U52 | 1/3 | 1 | 1/2 | 0.1634 | |
| U53 | 1/2 | 2 | 1 | 0.2970 | |

## 2.4. Determine the single factor evaluation matrix

The product of each fuzzy matrix and each single factor weight forms the matrix as follows:

$$D_A = \begin{bmatrix} 0.0110 & 0.0110 & 0.3273 & 0.6509 \\ 0.4692 & 0.3110 & 0.1891 & 0.0309 \\ 0.4512 & 0.4000 & 0.1366 & 0.0122 \\ 0.3846 & 0.4000 & 0.1895 & 0.0258 \\ 0.2787 & 0.4000 & 0.2916 & 0.0297 \end{bmatrix}$$

$$D_B = \begin{bmatrix} 0.1472 & 0.3472 & 0.3891 & 0.1166 \\ 0.0419 & 0.2837 & 0.3691 & 0.3054 \\ 0.2297 & 0.3122 & 0.4000 & 0.0581 \\ 0 & 0.2000 & 0.4000 & 0.4000 \\ 0.0297 & 0.2000 & 0.4079 & 0.3624 \end{bmatrix}$$

$$D_C = \begin{bmatrix} 0.0582 & 0.1891 & 0.3691 & 0.3837 \\ 0 & 0.1309 & 0.4582 & 0.4110 \\ 0 & 0.2230 & 0.4000 & 0.3770 \\ 0.0363 & 0.0726 & 0.2089 & 0.6822 \\ 0 & 0.1000 & 0.5000 & 0.4000 \end{bmatrix}$$

$$D_D = \begin{bmatrix} 0.1582 & 0.2110 & 0.4110 & 0.2200 \\ 0.0419 & 0.3000 & 0.3419 & 0.3163 \\ 0.1108 & 0.2878 & 0.4878 & 0.1136 \\ 0.0726 & 0.1089 & 0.4000 & 0.4185 \\ 0.2000 & 0.4460 & 0.3079 & 0.0460 \end{bmatrix}$$

$$D_E = \begin{bmatrix} 0.2472 & 0.4582 & 0.2638 & 0.0309 \\ 0.0837 & 0.3419 & 0.3582 & 0.2163 \\ 0.0122 & 0.1878 & 0.4878 & 0.3122 \\ 0.0726 & 0.2726 & 0.3637 & 0.2911 \\ 0.0297 & 0.3673 & 0.3000 & 0.1951 \end{bmatrix}$$

$$D_F = \begin{bmatrix} 0.0309 & 0.3054 & 0.4419 & 0.2219 \\ 0 & 0.1837 & 0.5000 & 0.3163 \\ 0 & 0.1122 & 0.3244 & 0.5634 \\ 0 & 0.1726 & 0.4000 & 0.4274 \\ 0 & 0.0297 & 0.2921 & 0.6782 \end{bmatrix}$$

The weight of five factors in the primary factor set W = [0.4455 0.1741 0.1057 0.2245 0.0502], multiply W by DA to obtain the evaluation result of scheme A:

MA=[0.23 0.21 0.25 0.30]

Similarly, the evaluation results of scheme B-F are as follows:

MB=[0.10 0.29 0.39 0.22]

MC=[0.03 0.15 0.36 0.46]

MD=[0.12 0.22 0.40 0.26]

ME=[0.15 0.36 0.33 0.16]

MF=[0.01 0.22 0.42 0.35]

### 2.5. Fuzzy comprehensive evaluation

For the evaluation results obtained in step E, this paper compares the sum of the "good and good" evaluation results of each scheme, and obtains the following fuzzy comprehensive evaluation results of six unmanned equipment operation schemes:

M=[0.44 0.39 0.18 0.34 0.51 0.23]

By normalizing the fuzzy comprehensive evaluation results, the following results are obtained:

M=[0.21 0.19 0.09 0.16 0.24 0.11]

## 3. Conclusion

From the above evaluation results, it can be seen that the application scheme of unmanned equipment in aerial photography accounts for 24% of the praise, followed by the application scheme of aerial broadcasting, accounting for 21%, and finally the application scheme of power grid maintenance, accounting for 9%. Therefore, through the evaluation, unmanned equipment can be preferentially selected for aerial photography as the best scheme. It can be seen from the evaluation process that the key of evaluation lies in the accuracy of expert scoring. Therefore, on the one hand, the setting of evaluation indicators should be clear and reasonable to minimize fuzziness, so as to improve the accuracy of expert scoring; On the other hand, the selection of experts should be comprehensive, involving all disciplines of unmanned equipment application, and the number of experts should be appropriate.

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