Research on equipment maintenance support based on fuzzy multiple attribute decision making

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Abstract. Aiming at the problem of equipment maintaining behaviours in equipment supporting action, with the help of fuzzy theory and multiple attribute decision-making, the paper analyzes influence factor and constraint condition. On this basis, the theory that equipment maintaining behaviours based on fuzzy multiple attribute decision making is presented. We can build model method of equipment maintaining behaviours choice, analyzing example. The conclusion proves correctness and feasibility of fuzzy multiple attribute decision making.

1 Introduction

The selection of equipment maintenance support model is a process of determining the best maintenance model, according to the current state of equipment. The decision of equipment maintenance model is determined based on the equipment health condition assessment and equipment fault prediction. The decision of equipment maintenance is a multi-attribute and multi-objective decision making, It requires consideration of the impact of multiple factors, such as fault risk, equipment availability, performance reliability and equipment maintenance costs. Due to the uncertainty and fuzziness of the related factors, we can use fuzzy theory and multi attribute decision making method to study the decision making of equipment condition maintenance. To reach the decision of equipment maintenance model based on fuzzy multiple attribute decision making method, one must consider the factors that influence the equipment maintenance decision. According to the characteristics of the combination of qualitative and quantitative indicators, the index weight of each index is determined by the fuzzy membership values. Finally, the equipment maintenance model is sorted by the value of the decision rules.

2 Fuzzy multi-attribute decision making theory

Fuzzy multiple attribute decision making(FMADM) is extension of multi-attribute decision making problem, The basic model of fuzzy multiple attribute decision making can be described as: Given a scheme set $A = (A_1, A_2, \ldots, A_m)$, Attribute set of each scheme $A = (A_1, A_2, \ldots, A_m)$, and Weight set of relative importance of each attribute W={W1,W2…Wn}. Among them, the method of expressing the attribute index and the weight value can be either digital or linguistic. The data structures involved may be imprecise or precise. However, all of the linguistic representation or imprecise attributes, weights and data structures are represented as fuzzy subsets or fuzzy numbers in the decision space. The fuzzy index value matrix $\tilde{F}$ can expressed as:

$$\tilde{F} = \begin{bmatrix} \tilde{f}_{11} & \tilde{f}_{12} & \cdots & \tilde{f}_{1n} \\ \tilde{f}_{21} & \tilde{f}_{22} & \cdots & \tilde{f}_{2n} \\ \vdots & \vdots & & \vdots \\ \tilde{f}_{m1} & \tilde{f}_{m2} & \cdots & \tilde{f}_{mn} \end{bmatrix}$$

Set weight set W to fuzzy numerical $\tilde{w}$, also set Index value matrix $\tilde{F}$ dimensionless standardized as $\tilde{F} = \left(f_{ij} \right)_{n \times m}$, The generalized fuzzy synthesis operator is used to transform the fuzzy weight vector $\tilde{w}$ and fuzzy index value matrix $\tilde{F}$, we can obtain fuzzy decision vector:

$$\tilde{D} = \tilde{w} \otimes \tilde{F} = (\tilde{d}_1, \tilde{d}_2, \cdots, \tilde{d}_m)$$

With appropriate fuzzy ranking method, sorting comparison of fuzzy decision vector elements, the scheme set can be selected $A = \{A_1, A_2, \cdots, A_m\}$, it is optimal scheme of set, sign as A_{max}.

3 Fuzzy multi-attribute decision making method

There are many methods of fuzzy multi-attribute decision making, taking into account the influence of multiple factors on the decision results, the decision of the equipment maintenance behaviours is needed, Therefore, we use the fuzzy weighted average method, Its mathematical expression is:

$$A^* = \left\{ \left(A_k | k \in I \right), \cup \left(A_k \right) = \max \left\{ \sum_{j=1}^{n} \tilde{w}_j \cdot \tilde{x}_{ij} \right\} \right\}$$

Among those, the utility value calculation process is as follows

Assumed function $g : R^{2n} \rightarrow R$ can change to $g(\tilde{z}_i) = \sum_{j=1}^{n} \tilde{w}_j \cdot \tilde{x}_{ij} / \sum_{j=1}^{n} \tilde{w}_j$.

In the formula, $\tilde{z}_i = \left(\tilde{w}_1, \tilde{w}_2, \cdots, \tilde{w}_n; \tilde{x}_{i1}, \tilde{x}_{i2}, \cdots, \tilde{x}_{in} \right)$, in product space R^{2n}, define the following subordinate functions:

$$\mu_{\tilde{z}i}(z) = \left[\bigwedge_{j=1}^{n} \mu_{\tilde{w}j}\left(w_j \right) \right] \wedge \left[\bigwedge_{j=1}^{n} \mu_{\tilde{x}ij}\left(x_{ij} \right) \right]$$

Through mapping can generate fuzzy utility set $\tilde{U}_i = g(z_i)$

It have subordinate function

$$\mu_{\tilde{U}_i}(u) = \sup_{z : g(z) = u} \mu_{\tilde{z}i}(z), \forall \mu \in R$$

It is assumed that the decision problem of precise and fuzzy concept can be used as trapezoidal fuzzy numbers, the fuzzy utility function use form of simple weighted average, such as:

$$\tilde{U}_i = \sum_{j=1}^{n} \tilde{w}_j \cdot \tilde{x}_{ij} / \sum_{j=1}^{n} \tilde{w}_j, i = 1, 2, \cdots, \ m$$

In the equation, w_j and x_{ij} is trapezoidal fuzzy number or ordinary real numbers. The maintenance behaviour is determined by maximizing the fuzzy utility value for the optimal maintenance behaviour.

$$U_{max} = \max \left\{ \tilde{U}_i \right\}, i = 1, 2, \cdots, m$$

4 Case analysis

Aviation weapon equipment belongs to complex weapon system, the condition-based maintenance can improve operational readiness. The evaluation of maintenance plan involves many factors and

attributes, Because of the comparison of information, we can not be measured in a strict standard, it is a vague concept, therefore, fuzzy decision method is introduced to determine the maintenance plan.

Generally speaking, the decision of equipment maintenance behaviour is mainly to solve the problem whether the equipment is repaired or repaired. We known equipment condition maintenance type is diversity. Maintenance activities are divided into early overhaul, preventive maintenance, continuous monitoring, regular testing and other. According to the characteristics of equipment maintenance and condition monitoring. Determine the equipment condition maintenance as: early overhaul, preventive maintenance and continued monitoring three scheme. Maintenance behaviour scheme set is $A = \{A_1, A_2, A_3\}$, Through analysis, the maintenance plan should take into account the influence of equipment failure risk, maintenance cost, availability and reliability. On the basis of taking into account the combat performance and economy, the following indexes are selected to constitute the attribute set: C1 is Maintenance cost, consider the economic affordability of maintenance. C2 is availability. C3 is maintenance risk, in order to minimize maintenance risk. C4 is reliability, reduce the risk of failure. C5 is working condition. We set up maintenance behaviour attribute set $C = \{C_1, C_2, C_3, C_4, C_5\}$.According to the equipment maintenance plan set and behaviour attribute set. The equipment maintenance support personnel and design technical personnel to evaluate the equipment maintenance behaviour attributes, the evaluation results of maintenance behaviour and decision attributes can be obtained. As shown in Table 1.

Table 1 evaluation results of maintenance behaviour set and attribute set

scheme	C1	C2	C3	C4	C5
A1	high	higher	high	Good	general
A2	general	general	general	preferably	preferably
A3	low	lower	low	general	general
weight	general	general	general	general	important

In order to ensure scientific and accurate decision making, it is necessary to convert the qualitative description index to the quantitative index represented by trapezoidal fuzzy number. Among those, maintenance cost, availability and risk are the cost indicators, reliability and working conditions for revenue indicators. The correspondence between the two is shown in Table 2.

Table 2: the relationship between the qualitative description and the membership function of fuzzy numbers

Serial number	Subordinate function	Cost index	Income index	weight
1	(0,0.1;0,0.2)	high	bad	unimportance
2	(0.3,0.3;0.15,0.15)	higher	good	important
3	(0.5,0.5;0.15,0.15)	general	general	General
4	(0.7,0.7;0.15,0.15)	lower	better	important
5	(0.9,1.0;0.2,0)	low	good	Important

According to the correspondence between the qualitative description and the membership function, according to the evaluation results of behaviour sets and attribute sets in Table 1, we can build fuzzy number decision matrix for maintenance behaviour.

By using the simple weighted average method, the fuzzy utility values of each maintenance behavior can be obtained by calculation

$$\widetilde{U}_1 = \sum_{j=1}^{5} \widetilde{w}_j \cdot \widetilde{x}_{1j} / \sum_{j=1}^{5} \widetilde{w}_j = （0.362, 0.417；0.104, 0.088）$$

$$\widetilde{U}_2 = \sum_{j=1}^{5} \widetilde{w}_j \cdot \widetilde{x}_{2j} / \sum_{j=1}^{5} \widetilde{w}_j = （0.597, 0.6；0.147, 0.092）$$

$$\tilde{U}_3 = \sum_{j=1}^{5} \tilde{w}_j \cdot \tilde{x}_{3j} / \sum_{j=1}^{5} \tilde{w}_j = （0.672, 0.7；\ 0.172, 0.088）$$

The comparison is made with fuzzy set ranking method, we can obtain $\tilde{U}_3 > \tilde{U}_2 > \tilde{U}_1$

Because the difference of the two fuzzy numbers is relatively small, it is possible to get different results with other fuzzy sets, we don't talk too much here.

Therefore, it can be concluded that $A_3 > 2_A > A1$，The comprehensive utility of A3 is the best, and it should be monitored continuously.

5 Concluding remarks

The decision making of equipment maintenance involves multiple evaluation indexes, which should be a fuzzy concept. It can not be judged by a judgment standard, so it is necessary to introduce the fuzzy decision method to evaluate the limited maintenance scheme. In the example, 5 indexes which have important effect on the evaluation of the scheme are selected, comprehensive analysis using 3 schemes. The results show that it is feasible to apply fuzzy multiple attribute decision making method to optimize equipment maintenance scheme.

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