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Study on the Decision-making Method of Aviation Equipment Development Process Based on Vague Set Paper Title

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Abstract: This study aims at decision-making in the process of aviation equipment development, analyzes the current score function of adopting the existing Vague sets to do the multiple criteria fuzzy decision-making, establishes a new scoring function, puts forward a decision-making method of aviation equipment development process based on Vague set, thus offers an effective method for the control of the aviation equipment development process.

Key words: Aviation equipment, vague set, decision-making method, score function

INTRODUCTION

Aviation projects have a long operation cycle and involve a wide range of subjects, resulting in great uncertainty of the projects, which will likely cause deviation between the actual progress and the plan. However, aviation projects require collaborative work and have complex overall organizational structure. Even tiny delays may lead to delays in the overall time duration of the project. While many factors may contribute to the progress control of aviation projects, the final result of the project is a comprehensive index. Therefore, to accomplish the project according to the expected progress requirement, one needs to constantly coordinate and optimize in the project management process.

In the decision-making support system of aviation projects, usually one best target is chosen among multiple targets in accordance with the relevant constraints. But because of the limited knowledge, constraints are often uncertain or not clear. So, it is difficult to carry out direct quantitative analysis. The uncertainty of interference factors is reflected in the various stages of progress control. Any interference factor during the project operation process could cause delay or failure of the project. Considering the uncertainty of interfering factors of aviation projects' progress control, it is significant for one to select a more effective execution plan with the help of a scientific decision-making method in the process control of aviation projects.

Vague sets Gau and Buehrer (1993) is a concept proposed by Gau and Buehrer (1993). It is an extension of Zadeh fuzzy set Zadeh (1965) and is similar to the intuitionist fuzzy sets Atanassov (1986) proposed by Atanassov. This concept is characterized by taking into account both the membership and non-membership information. So it has a stronger representation capability than the traditional fuzzy sets in dealing with the uncertain information, which helps to efficiently select a clear and suitable proposal in the decision-making support system of aviation projects.

BASIC CONCEPT AND OPERATION OF VAGUE SETS

Basic concepts of vague sets: The traditional fuzzy set theory adopts a single value of membership $\mu_A(\mu_i)\in[0, 1]$ (in which , $\mu_i\in U$, U is the domain, and A is a fuzzy set of U) to represent the membership. In Vague set, A is a Vague set of U, with a true membership function $t_A(\mu_i)$ and a false-membership function $f_A(\mu_i)$ to describe the boundaries of the membership. The two boundaries make a subinterval $[t_A(\mu_i), 1\text{-}f_A(\mu_i)]$ of the interval([0, 1), in which $t_A(\mu_i)\le\mu_A(\mu_i)\le 1\text{-}f_A(\mu_i)$ this interval is the membership of μ_i in the Vague sets A, $\mu_A(\mu_i)$. When U is discrete, denoted by:

$$A=\frac{\sum_{i=1}^{n}\left[t_A\left(u_i,1-f_A\left(u_i\right)\right)\right]}{u},u_i\in X$$

where, U is continuous, denoted by:

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$$A = \frac{\int_u [t_A(u), 1 - f_A(u)]}{u}, u \in U$$

$$\pi_A(u) = 1 - t_A(u) - f_A(u)$$

is the vague degree of u against Vague set A, it is a measure of the vagueness degree of u against Vague set. It's a measure of the unknown information of u on A. The larger the value of $\pi_A(u)$, the more unknown information of u on A. To explain the concept of Vague sets using voting model example: Suppose $u_A(u) = (0.4, 0.8)$, then:

$$t_A(u) = 0.4,\ f_A(u) = 1 - 0.8 = 0.2$$

$$\pi_A(u) = 1 - t_A(u) - f_A(u) = 0.4$$

the degree of element u belonging to A is 0.4; the degree of u not belonging is 0.2. The degree of hesitation is 0.4, that is, four votes are in favor of it, two votes are against it and four abstentions.

Vague value and the computing and relation rules of vague sets: Suppose vague value:

$$x = [t_x, 1 - f_x],\ y = [t_y, 1 - f_y]$$

where, t_x, f_x, $f_y \in (0, 1)$ and $t_x + f_x \leq 1$, $t_y + f_x \leq 1$.

Define the calculation and relationship of vague value as follows:

$$x \wedge y = [\min(t_x, t_y), \min(1 - f_x, 1 - f_y)]$$

$$x \vee y = [\max(t_x, t_y), \max(1 - f_x, 1 - f_y)]$$

$$x = y \Leftrightarrow t_x = t_y \text{ and } f_x = f_y,\ x \leq y \Leftrightarrow t_x \leq t_y \text{ and } f_x \geq f_y,\ \bar{x} = [f_x, 1 - t_x]$$

Suppose A and B are two Vague sets on the domain U, which:

$$A = \sum_{i=1}^{n} [t_A(x_i), 1 - f_A(x_i)] / x_i$$

$$B = \sum_{i=1}^{n} [t_B(x_i), 1 - f_B(x_i)] / x_i \quad (1)$$

Define the calculation and relationship of Vague set as follows:

$$A \subseteq B \Leftrightarrow \forall x_i \in U,\ t_A(x_i) \leq t_B(x_i) \text{ and } f_A(x_i) \geq f_B(x_i)$$

$$A = B \Leftrightarrow \forall x_i \in U,\ t_A(x_i) = t_B(x_i) \text{ and } f_A(x_i) = f_B(x_i)$$

$$A \cap B = \sum \{[t_A(x_i), 1 - f_A(x_i)] \wedge [t_B(x_i), 1 - f_B(x_i)]\} / x_i$$

$$A \cup B = \sum \{[t_A(x_i), 1 - f_A(x_i)] \vee [t_B(x_i), 1 - f_B(x_i)]\} / x_i$$

$$\bar{A} = \sum_{i=1}^{n} [f_A(x_i), 1 - t_A(x_i)] / x_i$$

DECISION-MAKING VAGUE SET METHOD OF AVIATIONEQUIPMENTDEVELOPMENTPROCESS

Existing score functions: F According to the evaluation function E, scholars have put forward a number of sorting methods. The score function mainly solves the problem of suitability between candidate proposal A_i and decision makers' requirements.

The score function Xu and Wei (2010) proposed by Chen and Tan:

$$S(E(A_i)) = t_{A_i} - f_{A_i} \quad (2)$$

They pointed out that the larger the value $S(E(A_i))$, the better the program meets the requirements of decision-makers. The starting point of the Eq. 2 is that the more advantages the true membership function has over the false membership function, the better it can meet the requirements of the decision makers.

Xu and Wei (2010) pointed out that the Eq. 2 will encounter difficult decision-making in the following situations:

- Example 1 If:

$$E(A_1) = [0.3, 0.9],\ E(A_2) = [0.5, 0.7]$$

Then:

$$S(E(A_1)) = 0.2,\ S(E(A_2)) = 0.2$$
$$S(E(A_1)) = S(E(A_2))$$

so it can not make decisions.

To this end, Hong and Choi proposed new scoring function:

$$H(E(A_i)) = t_{A_i} + f_{A_i} \quad (3)$$

They pointed out that the larger the $H(E(A_i))$ value, the better proposal A_i can meet the requirements of the decision-makers. The starting point of the Eq. 3 is that the more known information, the better it can meet the requirements of the decision-makers. In decision making, people often want to know as much information as possible so as to reduce the impact of uncertainty impact.In Example 1:

$$H(E(A_1)) = 0.3 + 0.1 = 0.4$$

$$H(E(A_2)) = 0.5 + 0.3 = 0.8$$

and therefore A_2 is superior to A_1.

After analyzing the inadequacies of Eq. 3, LiFan proposed to define two functions, S_1 and S_2, respectively, so as to indicate the degree to which solution A_i can or can not meet the requirements of the policymakers:

$$S_1 = t_{A_i},\ S_2 = 1 - f_{A_i} \text{ or } S_1 = t_{A_i} - f_{A_i} \quad S_2 = 1 - f_{A_i} \tag{4}$$

The decision The rule is: to sort according to the value of S_1, the larger the value is, the better solution A_i can meet the requirements of the decision makers. When the values of S_1 are the same, then sort according to the value of S_2 the large the value is, the better solution A_i can meet the requirements of policymakers.

The above sorting method of score functions didn't consider the impact of the abstaining part on the decision-making effect. Much information is during decision-making.

Xu and Wei (2010) analyzed the abstaining part reflected by the evaluation function E, taking into account the fact that some of the people who abstained might tend to vote in favor, some tend to vote against it while some others still tend to abstain. As for the abstained part π_{Ai}, it can be subdivided into three parts according to the results of the votes: $t_{Ai}\ \pi_{Ai}$, $f_{Ai}\ \pi_{Ai}$ and $(1\text{-}t_{Ai}\text{-}f_{Ai})\ \pi_{Ai}$, denoting, respectively the proportion of people who incline to vote in favor, against and abstain. He proposed the following scoring function:

$$L(E(A_i)) = t_{A_i} + t_{A_i}(1 - t_{A_i} - f_{A_i}) \tag{5}$$

He pointed out that the larger the value of $L(E(A_i))$, the better solution A_i can meet the requirements of policymakers. This method considers the impact of the supportive opinions on policymakers while neglecting the impact of objection on policymaking effect, which is a relatively positive method of policymaking.

Example 2 If:

$$E(A_1) = [0.4, 0.4],\ E(A_2) = [0.2, 0.1]$$

From function 5:

$$L(E(A_1)) = 0.4,\ L(E(A_2)) = 0.36$$

This means solution A_1 is superior to A_2.

However, if explain this in vote model, solution A_1 has four votes in favor, 6 votes against it and no abstention; solution A_2 has 2 votes in favor, no objection and 8 abstentions. In practice, people might choose solution A_2. To solve this problem, Zhou zhen put forward a new scoring function.

Zhou Zhen put forward a new score function (4):

$$Z(E(A_i)) = t_{A_i} - f_{A_i} + (\alpha - \beta)\pi_{A_i} \tag{6}$$

where, $0 \le \alpha$, $\beta \le 1$, $0 \le \alpha + \beta \le 1$, the value range of α and β is as follows: in general situation, i.e. when:

$$t_{A_i} - f_{A_i} \ne 0,\ \alpha = t_{A_i},\ \beta = f_{A_i}$$

So:

$$Z(E(A_i)) = (t_{A_i} - f_{A_i})(1 + \pi_{A_i})$$

However, this method does not apply to the situation when:

$$t_{A_i} - f_{A_i} = k(-0.2 < k < 0.2)$$

for instance, in example 1:

$$Z(E(A_1)) = 0.32,\ Z(E(A_2)) = 0.24$$
$$Z(E(A_1)) > Z(E(A_2))$$

Therefore, solution A_1 is superior to A_2.

Decision-making of aviation equipment development process based on vague sets: Due to the special nature of the aviation project, one needs to consider the schedule, cost and risk, which requires a sufficient amount of information. In terms of voting model, people who support or oppose have their reasons, while abstentions make both positive and negative sides hesitant, or unclear about the situation with minimum information. Therefore, to optimize the decision-making in aviation projects, one can set different proportions for people who are in favor of it, against it and abstain. The score function is:

$$Y(E(A_i)) = \alpha t_{A_i} + \beta(1 - f_{A_i}) + \gamma(f_{A_i} - t_{A_i}) \quad (7)$$

Among them, there's a lager proportion for the pros and cons due to the larger amount of information while a smaller proportion for abstentions due to the smaller amount of information. When setting weight, α is a positive value and β is a negative value. The value of γ is decided according to the type of decision-makers. One can adopt a positive value for the optimist while a negative value or 0 for the pessimist, and it should also meet the following Eq:

$$\alpha - \beta + \gamma = 1$$

CASE STUDY

Suppose there are three decision-making solutions, A_1, A_2 and A_3. Represented as A = (A_1, A_2, A_3). One should consider three criteria in the selection process: C_1 (progress), C_2 (expenses) and C_3 ((risk). The feature of solutions A_1 (i = 1, 2, 3) under constraint set C can be represented by the following Vague sets:

$$A_1 = \{(C_1, [0.2, 0.8]), (C_2, [0.3, 0.8]), C_2, [0.2, 0.9])\}$$

$$A_2 = \{(C_1, [0.2, 0.7]), (C_2, [0.3, 0.9]), C_2, [0.3, 0.8])\}$$

$$A_3 = \{(C_1, [0.3, 0.9]), (C_2, [0.3, 0.8]), C_2, [0.4, 0.6])\}$$

Decision-makers should choose a solution that can meet the conditions of C_1, C_2 and C_3 at the same time, in other words, the requirements of the decision-makers are C_1 and C_2 and C_3. According to the algorithm of Vague set, the evaluation function of the decision-making solutions are as follows:

- One can see that solution A_1 is optimal, followed by solution A_3 and solution A_2

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