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Research Article

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Application of improved OWA operator and intuitionistic fuzzy sets in decision-making of jack-up drilling platform design scheme

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ABSTRACT

The choice of jack-up drilling platform design scheme plays a key role in construction and use of platform. In order to get satisfactory design scheme, we propose that intuitionistic fuzzy sets and OWA operator can be applied into the decision-making of jack-up drilling platform design scheme. After using intuitionistic fuzzy sets to reflect decision makers' various preferences, using OWA operator to integrate group opinion. Then we calculate relative closeness coefficient between ideal scheme and each scheme thus choose a satisfied design scheme. Finally, an Instance illustrates the effectiveness of the proposed method.

Keywords: Intuitionistic fuzzy, OWA operator, Jack-up drilling platform, Decision making.

INTRODUCTION

As the global demand for energy is widening, offshore oil resources that accounts for about 34% of the world's resources has become largely attention, Jack-up drilling platform as important tool to marine energy exploration and development, has received the widespread attention throughout the world[1]. However jack-up drilling platform is a complex ocean engineering, Its scientific design scheme decision-making is very significant, The process not only promote the communication between the related personnel such as designer, ship-owners, builder and so on, but make them understand of design scheme better. In addition, scientific evaluation of jack-up drilling platform design scheme can find the problem in advance thus further improve the design.

For multiple attribute group decision making problems, there are many widely-used method which includes analytic hierarchy process (AHP) and grey correlation method, genetic algorithm, etc. However, each method has certain limitations, In addition, in the evaluation index weight, the decision makers are often based on experience, professional knowledge, to give precision value, ignoring the influence of uncertain information for decision making [2]. Therefore, we established a decision-making model of jack-up drilling platform under uncertain information environment. With the introduction of intuitionistic fuzzy sets to represent uncertain information [3], using OWA operator that includes quantitative and qualitative analysis to integrate individual fuzzy language to a group decision, we can take every decision makers' preference or needs into full consideration; finally get the most well-pleasing design scheme.

EXPERIMENTAL SECTION

2. Decision makers and attribute analysis of jack-up drilling platform design scheme

Platform scheme decision is a complex multiple attribute decision-making problems which involves the following aspects: firstly, the determination of relevant policymakers who participate in the evaluation of decision-making process; secondly, the determination of attribute values, and it determines what specific indicators.

2.1 Determination of relevant policy makers

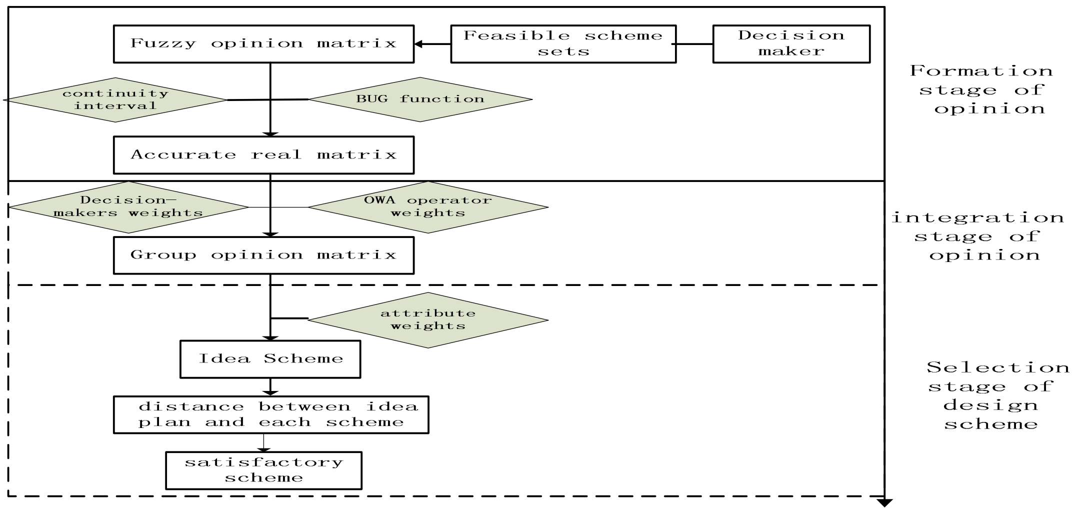
With long construction cycle, large investment and high risk of Jack-up drilling platform, the scientific design scheme is the key to its future application. It is important to take the various stakeholders into decision makers in the evaluation of design scheme. Firstly, ship owners use the platform directly, and their needs are critical to project success, it is necessary to set them into the decision makers. Secondly, the construction of platform is based on operable and practical design scheme, thus, the builder should be choice as decision-maker. Design engineers make design schemes according to intelligent system, they have a more profound understanding to design scheme than other decision makers, and therefore their evaluation is more accurate. In addition, the related domain experts should participate in the scheme choice, because experts with rich professional knowledge can evaluate platform scheme objectively and professionally. Different decision makers can integrate demand and knowledge well and form complementary advantages, in order to choose satisfactory solution.

2.2 Determination of scheme property values

Decision makers evaluate each design scheme on the basis of the attribute, and the attribute will directly affect the scheme of choice. Thus the determination of design scheme attribute value is of great significance for satisfactory solution. First of all, if the price of platform is not accepted, it is impossible to enter market. There is something, such as amount of steel, affect the cost of platform. Under the premise of guaranteeing the quality how to make the use of resources and energy efficiency be best is one of the important evaluation standard to the choice scheme, therefore, we should consider the economy of design scheme. Secondly, sea wind, wave and flow makes work environment potentially dangerous, we need stable and reasonable platform to ensure the safety of the operation environment, the safety of design scheme should be considered. In addition, the offshore deep-water environment is bad, often r getting more energy from such an environment and meeting the basic needs of customers rely on advanced technology of the platform. What is more, the advanced technology is the guarantee of economy and safety of the platform.

3. Three stage decision model of jack-up drilling platform design scheme

A good evaluation model for the processing of decision problem is critical, and platform design scheme selection evaluation is a complex multiple attribute decision making problems, we establish a three phase model of decision mechanism based on intuitionistic fuzzy sets and OWA operator as below:



Graph1: three stages decision-making mechanism of jack-up drilling platform scheme

We define decision making problem of jack-up drilling platform scheme as follows: design schemes: $X=(x_1, x_2, x_3 \ldots.. x_i)$, $i=1,2,.....m$; Attributes of scheme: $U=(u_1, u_2, u_3.....u_j)$;

Attribute weights: $\alpha = (\alpha_1, \alpha_2, \ldots \alpha_j)$ $\sum_{j=1}^{n} v_j = 1$, $j=1,2,.....n$;Decision makers:

$D = (D_1, D_2, \ldots, D_k)$;Decision makers weights: $v=(v_1, v_2.....v_k)$, $\sum_{k=1}^{w} \alpha_k = 1$, $k=1,2,....w$.

3.1 Formation stage of decision makers' opinion
3.1.1 Fuzzy assignment of each attribute

Traditionally, we usual to assign attribute in precision value. It will ignore easily uncertainty and Information of original information. Atanassov proposed that intuitionistic fuzzy sets can be fully described the decision making problem and various states of people decision-making behavior, coordinating the relationship between the clarity and credibility[4].

We call $A=\{<x,\mu(x),f(x)>\,|\,x\in X\}$ as an intuitionistic fuzzy set of X which is non-empty set, and call $\mu(x)$ as subordinate function belongs to intuitionistic fuzzy set A, $\mu(x)$ shows the lower limit of support degree of $x\in A$. $f(x)$ is said to describe as a greatest lower bound of opposition to $x\in A$. $\tau(x)=1-\mu(x)-f(x)$ shows the degree of uncertainty and hesitation of $x\in A, 0\le\mu(x), f(x),\tau(x)\le 1$ [5][6].

Decision makers do a fuzzy assignment to use the form of $[\mu(x), f(x)]$ to assign the attributes of design scheme with their own experience or preference, and then form the decision makers' intuitionistic fuzzy matrix: D_{ij}^{k}, $\mathrm{k}=1,2,3...n$.

3.1.2 Using BUG function to form precise real matrix

Considering the fuzzy number cannot be directly compared or assembled, firstly, we transfer each element in D_{ij}^{k} into a form of continuous interval function. It turns the intuitionistic fuzzy sets $[\mu(x), f(x)]$ into intuitionistic fuzzy continuous interval $[\mu(x),1-f(x)]$ which indicates rang of decision makers' preference. Secondly, we use the BUG function to convert it into discrete accurate real number. BUG function is a kind of integrated functions [7]. If [a, b] is interval number, there areas follow:

$$g_Q([a,b])=\int_0^1\frac{dQ(\mathrm{y})}{dy}b-y(b-a)dy \tag{1}$$

Here, $a\le g([a,b])\le b$, Q is BUG function, g is a function of continuum integration.

Generally, $\mathrm{Q}(\mathrm{y})=y^r$, we plug it into formula (1) as follow:

$$g_Q([a,b])=\frac{b+ra}{r+1} \tag{2}$$

As a result, by formula (2) the intuitionistic fuzzy interval $[\mu(x),1-f(x)]$ can be turned into discrete accurate real number:

$$g=\frac{1-f(x)+r\mu(x)}{r+1} \tag{3}$$

Finally, the decision-making accurate matrix A_{ij}^{k} is formed.

3.2 Integration stage of decision makers' opinion

We introduce OWA operator to deal with integration of decision makers' opinion. OWA operator, put forward in 1988 by American professor Yager, is a method of data fusion [8][9].

Setting $OWA:(\mathrm{a}_1,\mathrm{a}_2,\ldots,\mathrm{a}_n)$ is a set of given data:

$$OWA_w(\mathrm{a}_1,\mathrm{a}_2,\ldots,\mathrm{a}_n)=\sum_{j=1}^{n}\omega_j b_j \tag{4}$$

Here, $\omega=(\omega_1, \omega_2, \ldots, \omega_n)^T$ is the weight vector of OWA operator, $\omega \in [0,1], 1 \le j \le n$

$\sum_{j=1}^{n} \omega = 1$, b_j is the jth biggest element in $(a_1, a_2, \ldots, a_n)$ .OWA operator is called ordered weighted arithmetic average operator.

3.2.1 Calculation of OWA operator weight

Yager has proposed to use orness measure (degree of optimism of decision makers) to consider operator weight. In order to make weight fairer, some scholars established weight solution model based on maximum entropy principle combined with degree of optimism of decision makers [10]. The model is as follows:

$$\text{orness}\ (\omega)=\sum_{j=1}^{n} \frac{n-j}{n-1}\omega_j = \beta \tag{5}$$

$$\omega_j - \frac{1}{n} - e_j^+ + e_j^- = 0, e_j^+ \ge 0. e_j^- \ge 0$$

Here, $\sum_{j}^{n} \omega_j = 1, \omega_j \in [0,1]$, $\frac{1}{n}$ indicates possibility distribution; e_j^+, e_j^- Said of the deviation.

This algorithm is not only simple, but reasonably takes the degree of subjective preferences of decision-maker into consideration, and objectively eliminates the unreasonable situation, so the article adopts the method of calculating weight to integrate decision-making advice.

3.2.2 Integrating each decision-maker's opinion to Group opinions with OWA operator

We improved formula (4) to get group opinion to attribute U_j of scheme X_i as follow:

$$b_{ij} = OWA_\omega(v_1 a_{i1}, v_2 a_{i2}, \ldots v_k a_{ik}) = \sum_{m=1}^{k} \omega_m n e_m \tag{6}$$

Here, v_k is decision makers' weight, a_{ik} is an accurate value that the kth decision maker assigns the attribute U_j of scheme X_i ,e_m is the mth biggest element in $(v_1 a_{i1}, v_2 a_{i2}, \ldots v_k a_{ik})$, ω_m is the weight of OWA operator, n is equilibrium factor which is in order to make the consistency of the data measured after integrating individual opinion into group opinion. Therefore group opinion b_{ij} to attribute U_j of scheme X_i can form group decision matrix E_{ij} .

3.3 Selection stage of design scheme

We choose the satisfactory design scheme based on looking for ideal scheme.

A.We standardize the group decision matrix E_{ij} by formula (7). After attribute weights are weighted to it, a new decision matrix H_{ij} can be got.

$$h_{ij} = (b_{ij} / \sqrt{\sum_{i,j=1}^{m,n} b_{ij}^2})\alpha_j \tag{7}$$

B.All attributes of design scheme are benefit type, so:

positive ideal scheme： $X^* = \{h_1^*, h_2^* \ldots h_i^*\}$ ， $h_i^* = \{\max h_{ij}\}$

negative ideal scheme： $X^- = \{h_1^-, h_2^- \ldots h_i^-\}$ ， $h_i^- = \{\min h_{ij}\}$

C.Calculate the distance between the ith scheme and positive ideal scheme:

$$d_i^* = \sqrt{\sum_{i=1}^{n}(h_{ij} - h_i^*)^2} \tag{8}$$

Calculate the distance between the ith scheme and negative ideal scheme:

$$d_i^- = \sqrt{\sum_{i=1}^{n}(h_{ij} - h_i^-)^2} \tag{9}$$

D.Calculate relative closeness coefficient between ideal scheme and each scheme:

$$D_i = \frac{d_i^-}{d_i^- + d_i^*} \tag{10}$$

Here, the larger D_i is, the more optimal the design scheme is.

4. Calculation examples

An ocean shipping enterprise use IDS-SEDU intelligent systems to design three kinds of jack-up drilling platform design scheme. Decision makers evaluate these three kinds of design scheme according to the attributes which are safety, economy, and advanced technology. We Set design schemes as $X = (x_1, x_2, x_3)$, attributes of design scheme as $U = (u_1, u_2, u_3)$, decision makers sets as $D = (D_1, D_2, D_3, D_4, D_5)$.In addition, we assume decision makers weights are $v = (0.20, 0.2, 0.15, 0.15, 0.30)$ and decision makers weights are $\alpha = (0.4, 0.3, 0.3)$.

First stage: formation of the decision makers' opinion:

Step 1: decision makers assign attributes of each design scheme in the form of $[\mu(x), f(x)]$, as following matrix:

$$D^1 = \begin{bmatrix} (0.65,0.25) & (0.70,0.15) & (0.85,0.10) \\ (0.70,0.15) & (0.90,0.05) & (0.75,0.20) \\ (0.85,0.10) & (0.75,0.15) & (0.70,0.25) \end{bmatrix} \quad D^2 = \begin{bmatrix} (0.70,0.25) & (0.85,0.10) & (0.80,0.15) \\ (0.65,0.20) & (0.80,0.05) & (0.70,0.10) \\ (0.75,0.10) & (0.65,0.25) & (0.90,0.05) \end{bmatrix}$$

$$D^3 = \begin{bmatrix} (0.60,0.25) & (0.75,0.15) & (0.80,0.15) \\ (0.75,0.15) & (0.85,0.05) & (0.75,0.20) \\ (0.85,0.10) & (0.80,0.10) & (0.90,0.05) \end{bmatrix} \quad D^4 = \begin{bmatrix} (0.80,0.15) & (0.75,0.15) & (0.80,0.10) \\ (0.85,0.10) & (0.80,0.15) & (0.70,0.25) \\ (0.65,0.25) & (0.85,0.05) & (0.80,0.15) \end{bmatrix}$$

$$D^5 = \begin{bmatrix} (0.80,0.15) & (0.85,0.05) & (0.75,0.20) \\ (0.65,0.15) & (0.70,0.25) & (0.85,0.10) \\ (0.85,0.10) & (0.65,0.25) & (0.70,0.25) \end{bmatrix}$$

Step 2: we turn each element $[\mu(x), f(x)]$ in the above matrix into intuitionistic fuzzy continuous interval $[\mu(x), 1-f(x)]$, and then setting BUG function as $Q(y) = y^{\frac{1}{2}}$, use the formula (3) to turn $[\mu(x), 1-f(x)]$ into discrete accurate real number, the following matrix can be developed:

$$A^1 = \begin{bmatrix} 0.72 & 0.80 & 0.89 \\ 0.73 & 0.93 & 0.77 \\ 0.87 & 0.82 & 0.73 \end{bmatrix} A^2 = \begin{bmatrix} 0.73 & 0.89 & 0.83 \\ 0.75 & 0.90 & 0.83 \\ 0.85 & 0.72 & 0.93 \end{bmatrix} A^3 = \begin{bmatrix} 0.72 & 0.82 & 0.83 \\ 0.82 & 0.92 & 0.78 \\ 0.89 & 0.87 & 0.93 \end{bmatrix}$$

$$A^4=\begin{bmatrix}0.73 & 0.82 & 0.87\\ 0.89 & 0.83 & 0.73\\ 0.72 & 0.88 & 0.83\end{bmatrix} A^5=\begin{bmatrix}0.83 & 0.92 & 0.78\\ 0.78 & 0.72 & 0.87\\ 0.89 & 0.68 & 0.73\end{bmatrix}$$

Second stage: Integration stage of opinion:

Step 1: calculate OWA operator weights, set optimism coefficient of decision makers as $\beta=0.6$, thus get the following linear optimization model according to the formula (5):

$$\min J=\sum_{j=1}^{5}(R_j^+ + R_j^-)$$

constraints: $\omega_1-0.2-R_1^+ + R_1^- =0$; $\omega_2-0.2-R_2^+ + R_2^- =0$;

$\omega_3-0.2-R_3^+ + R_3^- =0$; $\omega_4-0.2-R_4^+ + R_4^- =0$;

$\omega_5-0.2-R_5^+ + R_5^- =0$; $\omega_1+\frac{3}{4}\omega_2+\frac{2}{4}\omega_3+\frac{1}{4}\omega_4=0.6$;

$\omega j\ge 0, R_j^+\ge 0, R_j^-\ge 0, j=1,,,n$

We can get the optimal weight $\omega=$ （$0.3, 0.2, 0.2, 0.2\ , 0.1$）by using software Matlab.

Step 2: using formula (6) to integrate each decision maker's opinion, balance factor is set to 4.

$$b_{11}=OWA_{\omega}(0.2*0.72, 0.2*73, 0.15*0.72, 0.15*0.73, 0.3*0.83)$$
$$=OWA_{\omega}(0.144, 0.146, 0.108, 0.110, 0.249)$$
$$=(0.3*0.249+0.2*0.146+0.2*0.144+0.2*0.110+0.1*0.108)*4$$
$$=0.6620$$

The same procedure may be easily adapted to integrate other decision maker:

$$E_{ij}=\begin{bmatrix}0.6620 & 0.6212 & 0.7102\\ 0.6736 & 0.7122 & 0.7066\\ 0.7455 & 0.6484 & 0.6866\end{bmatrix}$$

Third stage: selection of design scheme

Step 1: standardizing matrix and weighting attribute weights to get as following:

$$H_{ij}=\begin{bmatrix}0.5502 & 0.5420 & 0.5848\\ 0.5598 & 0.6214 & 0.5817\\ 0.6196 & 0.5657 & 0.5653\end{bmatrix}$$

Step 2: Calculate the positive ideal scheme: $X^*=(0.6196\quad 0.6214\quad 0.5848)$

Calculate the negative ideal solution: $X^-=(0.5502\quad 0.5420\quad 0.5653)$

Step 3: Calculate the distance between each scheme and positive ideal scheme:

$$d_1^*=0.1054, d_2^*=0.0598, d_3^*=0.05896$$

Calculate the distance between each scheme and negative ideal scheme:

$$d_1^-=0.0194, d_2^-=0.0817, d_3^-=0.0733$$

Step 4: Calculate relative closeness coefficient between ideal scheme and each scheme:

$$R_1=0.0341, \mathrm{R}_2=0.1273, \mathrm{R}_3=0.1058$$

Ranking is $R_2 > R_3 > R_1$, therefore, design scheme 2 is selected as the jack-up drilling platform satisfying scheme.

RESULTS AND DISCUSSION

The development of the ocean drilling platform is of great significance to improve the ability of developing resources of ocean engineering and international competitiveness of ocean drilling platform, but also put forward higher requirements to the decision making of drilling platform scheme. Therefore, we build the three stage decision-making model of jack-up drilling platform scheme:

(1)In the first stage, Using intuitionistic fuzzy sets to form decision-making matrix can objectively express knowledge, experience of decision makers, but also is more in line with the thinking habits of people, giving full consideration to the effects of the uncertainty. We turn intuitionistic fuzzy assignment that isn't integrated into form of intuitionistic fuzzy interval, and further transfer it into precise real numbers through the BUG function. This method establishes a Bridges connecting intuitionistic fuzzy sets to OWA operator, and solves the problem that OWA operator can only deal with discrete precise data.

(2)Second stage provides the improved OWA operator to integrate each decision makers' opinion into group advice. Not only can it accurately describe the decision makers' preference degree, but give a low weight to extreme opinion, grasping the degrees between the subjective preference and objective data well. In addition, the OWA operator weighting method based on decision makers' optimism can make opinion gathered more in line with the decision-making problem situation.

(3)Third stage implies comparing the relative closeness coefficient between each scheme and ideal scheme to select satisfactory scheme. Ideal scheme approximation method doesn't calculate the precise composite scores of each scheme, which both comply with the intuitionistic fuzzy ideas of this article and have a more profound understanding to the existing scheme in order to clear improvement of design scheme.

This article try to relate intuitionistic fuzzy sets with OWA operator to establish a jack-up drilling platform scheme decision-making model, in order to reduce the unreasonable situation in the every decision-making stage. This model is a further supplement to group decision theory and method. Meanwhile, it has definite application meaning for platform evaluation and information fusion, data gathering. In addition, this paper still has somewhere to be worth to perfect, such as the calculation of decision makers' optimistic coefficient remains to be further discussed.

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