AG600 Maritime Base Location Decision Based on the Interval Intuitionistic Fuzzy TOPSIS Method

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**ABSTRACT** Aiming at the location research blank of the AG600 amphibious aircraft marine rescue base, the location decision index system of the AG600 is established, and the AG600 location decision model based on the interval intuitionistic fuzzy theory and improved TOPSIS method is constructed. Through investigation and statistical analysis, the evaluation system with 10 indices is determined based on applicability, safety, and accessibility, and in the process of quantization of index assignment, a fuzzy conversion method for different indices is proposed. The interval intuitionistic fuzzy number of each index is obtained by combining objective calculation and subjective assignment, and the interval intuitionistic fuzzy decision matrix is constructed. The fuzzy entropy method is used to calculate the index weight, and then the improved Technique for Order of Preference by Similarity (TOPSIS) is used to evaluate and rank the rescue bases, the scientific and reasonable location decision results are obtained. Moreover, STOPSIS and WS are used to analyze and demonstrate the sorting inversion problem, and the value is 0.908, which further proves the effectiveness of the method proposed in this paper. Finally, taking the South China Sea islands as an example, the correctness and reliability of the proposed model is verified by comparison with the calculation results of the score function method and the projection method.

**INDEX TERMS** AG600 amphibious aircraft, interval intuitionistic fuzzy TOPSIS, location decision, marine rescue base.

I. INTRODUCTION

AG600 is the latest large amphibious rescue aircraft developed by China. The purpose of AG600 maritime base location decision is to select the island that best meets to the AG600 deployment requirements among multiple islands, which is a multi-attribute fuzzy approaches the ideal solution problem with a completely unknown attribute weight. AG600’s scientific and reasonable deployment is the key to ensuring the rescue mission’s success rate and the rescue resources’ effective utilization, and is an important part of the application and exploration of AG600 in maritime rescue field. The key to solve the multi-attribute fuzzy decision-making problem is the construction of the evaluation index system and the determination of the index weight. On this basis, the decision-making model is constructed, and the final evaluation decision is completed according to the actual project demand and the appropriate evaluation method. The location decision of AG600 needs to consider various influencing factors such as applicability, accessibility, and safety. Owing to the complex and numerous evaluation indices, considerable fuzziness and uncertainty exist. Therefore, the location decision of AG600 is difficult to quantify with a deterministic mathematical model. Usage of site location decision methods is becoming more diverse each year, as more research of different fields researchers tries to provide a solution for their different study. For example those methods are used in warehouse site selection [1], school site selection [2], logistics site selection [3], wind farm site selection [4], Emergency airport site selection [5], cross-docking center location selection [6], sustainable offshore wind energy stations location selection [7], hospital site selection [8], ideal business location selection [9], retail shop site selection [10], solar site
selection [11], power plant site selection [12], landfill site selection [13], textile manufacturing facility site selection [14] etc. AG600 maritime base location decision is that aim at multiple islands in a certain sea area, through the comprehensive analysis of wind, wave, current, natural conditions of the island and hydrologic conditions around the island and other factors that affect the deployment and application of AG600 in the rescue space which the islands as the center and the half of the range of the AG600 amphibious aircraft as the rescue radius, getting the priority order of the islands. According to the needs and characteristics of AG600 location decision, combined with the comparative analysis of the application characteristics of various evaluation ranking methods, this paper chooses TOPSIS method as the evaluation method of AG600 location decision. The Technique for Order of Preference by Similarity (TOPSIS) [15]–[19] is one of the common methods to deal with the evaluation of multi-factor fuzzy approximation. It was first proposed by Wang and Yoon [20] in 1981. It is an effective method for sorting and optimizing existing objects according to the proximity of a limited number of evaluation objects to the ideal target, and it is suitable for AG600 location decision. There have been many related studies based on the TOPSIS method in site selection research. Chen [21] constructed a general airport site selection evaluation model based on the TOPSIS method. Zhang [22] provided a multi-criteria decision-making method based on Interval 2 Fuzzy Sets (IT2FS). It obtains comprehensive weights through the AHP method and the CRITIC method. The improved TOPSIS method is used for the site selection of nursing homes in a certain area. Zhou [23] constructed the location model of a biofuel refinery based on the TOPSIS method. Parkhan [24], referenced the analytic hierarchy process and TOPSIS method to build a shipyard location model. Alkan [16] constructed a hospital location model based on the circular fuzzy set and TOPSIS method. Jia [25] constructed the location model of a cold chain logistics distribution center based on the entropy weight method and TOPSIS method. Zhou [26] constructed the location model of pilot boarding to guide the pilot to board the ship to the optimal safety area under heavy wind and waves, based on the entropy weight method and TOPSIS method. It can be seen from previous research that the application of the TOPSIS method in the field of maritime rescue has been virtually nonexistent, and although most studies have established a corresponding evaluation index system, their method of index assignment and weight determination has been too simple. Owing to the limitation of the decision maker and the complexity of the site selection process, the diversity, uncertainty, and fuzziness of the information contained in the site selection process cannot be fully expressed. Interval intuitionistic fuzzy set theory (IVIFS) was proposed by Atanassow [27], [28]. Based on the concept of the intuitionistic fuzzy set, the membership degree, non-membership degree, and hesitation degree have been extended to the interval number, which is more flexible and practical in dealing with fuzziness and uncertainty. The relevant research on IVIFS has been mature and achieved abundant results [29]–[34].

Based on the interval intuitionistic fuzzy theory and TOPSIS evaluation method, considering the characteristics that the indexes of AG600 maritime base location decision is mainly interval number and linguistic indexes, the similarity approximation algorithm between the selected islands and the ideal rescue base in the form of interval intuitionistic fuzzy is adopted, this paper establishes the AG600 maritime base location decision model based on the improved interval intuitionistic fuzzy TOPSIS method. In the process of assigning weights to indicators, the diversity, uncertainty, and fuzziness of indicators as well as the fuzziness, hesitation, and limitation of experts’ understanding of evaluation indicators are considered. Unlike the Delphi method and other traditional methods, this paper proposes a fuzzy transformation method for different types of indicators and obtains the interval intuitive fuzzy number of indicators through the combination of objective calculation and subjective assignment. Based on this, the interval intuitionistic fuzzy decision matrix is established, the weight of each index is assigned by the fuzzy entropy method, the improved TOPSIS method is used to evaluate and sort selected bases, and finally, the location decision result of AG600 is obtained. The correctness and reliability of AG600 location selection model are verified by comparison with the calculation results of score function method and projection method. In practical application, the ranking results of rescue bases obtained have been recognized by rescue experts and first-line rescuers. This provides a new idea for AG600 site selection and makes the decision more scientific and reasonable.

II. AG600 SITE SELECTION DECISION INDEX SYSTEM

The decision of AG600 site selection at sea requires comprehensive consideration of the AG600 design parameters, rescue mode, deployment requirements, rescue objects, rescue space information, and other factors affecting AG600 site selection and deployment. This paper takes the South China Sea as the site selection research space. Through the statistical analysis of wind, waves, currents, and other meteorological information in the South China Sea, the natural conditions of more than 200 islands and reefs and their construction status, water depth data of waters with frequent accidents, distribution of channel anchorage, and distribution of bird gathering habitat and other information data [35]–[39], combined with the questionnaire survey and scoring of maritime rescue experts and AG600 R&D experts, the applicability, accessibility, and safety are taken as the evaluation criteria (Reference: Technical Standard for Civil Airport Flight Area (MH 5001-2021), Airport Design and Operation, International Aviation and Maritime Search and Rescue Manual, Civil Aviation Law of the People’s Republic of China, Emergency Response Law of the People’s Republic of China and other authoritative materials).10 evaluation indices affecting AG600 site selection at sea are obtained. The index value is divided into two categories, namely the numerical type,
TABLE 1. Evaluation index of AG600 maritime rescue base.

| Criterion | Indicator     | Type | Description                                      |
|-----------|---------------|------|--------------------------------------------------|
|           | Land airport  | $u_i$| A/B                                              |
|           | seadrome      | $u_i$| A/B                                              |
| Applicability | Water depth | $u_i$| A/B                                              |
|           | Support capacity | $u_i$| V/B Evaluation of medical treatment, supplies, navigation aid, and other rescue support capabilities. |
|           | Utilization efficiency | $u_i$| V/B Ease of navigation in the base and rescue space. |
| Reachability | Sea limit | $u_i$| A/B How fast the target is reached from the water. |
|           | airspace      | $u_i$| A/B How fast the accident area is reached from the air. |
|           | Wind          | $u_i$| A/C The maximum lateral wind force for takeoff and landing shall not exceed 10.3 m/s (Wind level 5) |
| Safety    | Wave          | $u_i$| A/C The wave height around the landing point shall not exceed 2.5 m |
| Visibility| $\mu_{i0}$    | A/B  | The days visibility in the rescue coverage area is not low 2 km |

marked as A, and the language description type, denoted as V. In terms of data impact, it can be divided into the benefit type and cost type. The benefit type indicator is represented by B, and the cost type indicator is represented by C, as shown in Table 1.

III. INTERVAL INTUITIONISTIC FUZZY ENTROPY AND FUZZY NUMBER CONVERSION

AG600 site selection is a decision process fraught with complexity and uncertainty. It can be seen from the AG600 site selection index system that the index includes two types: fuzzy number and language variable. There are many ways to calculate the index weight, but in the process of AG600 site selection, the influence of subjective factors should be avoided as much as possible in order to obtain objective results. In addition, incomplete and vague information may occur in the process of AG600 site selection, which requires that the weight calculation method can not only accurately reflect the lack of information, but also objectively obtain the weight of each attribute. Through comparative analysis of common objective index weight calculation methods, entropy weight method is the most suitable weight calculation method in this paper, which can meet the above requirements and often match TOPSIS method [40]–[42]. The entropy weight method is a common method to solve fuzzy uncertainty problems, and the combination of entropy weight method and fuzzy set and its extension theory is widely used, the technology is mature. Based on this, this paper adopts the interval intuitionistic fuzzy entropy method to calculate the weight of the evaluation index. The index considers the objective fact that index data cannot be expressed with accurate numbers and there are linguistic variables, and also takes into account the fuzziness and hesitation of experts’ understanding of the index.

A. INTERNAL INTUITIONISTIC FUZZY ENTROPY

**Definition 1** [27], [28]: Let us assume that $\text{int}[0,1]$ represents all of the closed subsets of interval numbers $[0,1]$, where $X$ is a given domain called

$$ A = \{ (x, \mu_A(x), v_A(x)) / x \in X \}, $$

which is the interval intuitionistic fuzzy set (IVIFSs($X$)) on domain $X$,

$$ \mu_A(x) : X \rightarrow \text{int}[0,1], v_A(x) : X \rightarrow \text{int}[0,1], $$

with $0 \leq \sup \mu_A(x) + \sup v_A(x) \leq 1, \forall x \in X$.

$$ \mu_A(x) = [\mu_A^L(x), \mu_A^U(x)] ; \ v_A(x) = [v_A^L(x), v_A^U(x)] $$

represents the membership degree and non-membership degree of element $x$ in $X$ belonging to $A$, and the interval intuitionistic fuzzy set $A$ can be written as

$$ A = \{ (x, [\mu_A^L(x), \mu_A^U(x)], [v_A^L(x), v_A^U(x)]) / x \in X \}, $$

where $\pi_A(x) = [\pi_A^L(x), \pi_A^U(x)] = [(1 - \mu_A^U(x) - v_A^U(x)], [1 - \mu_A^L(x) - v_A^L(x)]$ is called the hesitancy degree of the element $A$. In particular, when $\mu_A^L(x) = \mu_A^U(x), v_A^L(x) = v_A^U(x)$, the interval intuitionistic fuzzy set degenerates into the intuitionistic fuzzy set. In the simplified form, let us call $\alpha = ([a, b], [c, d])$ an interval intuitionistic fuzzy number, where $0 \leq a \leq b \leq 1, 0 \leq c \leq d \leq 1, 0 \leq b + d \leq 1$.

Assume that $X_\alpha = \{x_j \ | \ j = 1, 2, \cdots, n\}$ is a finite theory domain, and $W = \{w_j \ | \ j = 1, 2, \cdots, n\}$ is the weight vector. For two interval intuitionistic fuzzy sets, $A$ and $B$, construct the similarity formula [43] as

$$ S(A, B) = \frac{2 - \min \left\{ \mu_j^-, v_j^- \right\} - \min \left\{ \mu_j^+, v_j^+ \right\}}{2 + \max \left\{ \mu_j^-, v_j^- \right\} + \max \left\{ \mu_j^+, v_j^+ \right\}} \tag{1} $$

where

$$ \mu_j^- = [\mu_A^L(x_j) - \mu_B^L(x_j)], \ v_j^- = [v_A^L(x_j) - v_B^L(x_j)], $$

$$ \mu_j^+ = [\mu_A^U(x_j) - \mu_B^U(x_j)], \ v_j^+ = [v_A^U(x_j) - v_B^U(x_j)]. $$

**Definition 2** [29]–[34]: In the interval intuitionistic fuzzy multi-attribute decision-making problem, there are $m$ objects that need to be evaluated, and $n$ attributes. If the $j$ attribute
value \( r_{ij} \) of the object \( i \) that needs to be evaluated can be expressed as

\[
    r_{ij} = \left( \left[ \mu_{ij}^L, \mu_{ij}^U \right], \left[ v_{ij}^L, v_{ij}^U \right] \right),
\]

\( i = 1, 2, \ldots, m; j = 1, 2, \ldots, n \),

then, the interval intuitive fuzzy entropy of attribute \( j(1, 2, \ldots, n) \) is

\[
    E_j = \frac{1}{m} \sum_{i=1}^{m} e \left( r_{ij} \right) = \frac{1}{m} \sum_{i=1}^{m} \frac{4 - \left[ \mu_{ij}^L - v_{ij}^L \right] + \left[ \mu_{ij}^U - v_{ij}^U \right]}{8} + \left[ \nu_{ij}^L + \nu_{ij}^U \right]^2.
\]

(2)

In sum, the weight of attribute \( j \) can be expressed as

\[
    w_j = \frac{1 - E_j}{n - \sum_{j=1}^{n} E_j}.
\]

(3)

Definition 3 [27]: Assume that \( \alpha_j = \left( \left[ a_{ij}, b_j \right], \left[ c_j, d_j \right] \right) \) \( (j = 1, 2, \ldots, n) \) is a group of interval intuitive fuzzy numbers, and \( F_w(\alpha_1, \alpha_2, \ldots, \alpha_n) \) is an interval intuitive fuzzy weighted arithmetic average operator with the following formula:

\[
    F_w(\alpha_1, \alpha_2, \ldots, \alpha_n) = \frac{\sum_{j=1}^{n} w_j \alpha_j}{\sum_{j=1}^{n} w_j},
\]

\[
    = \left[ \frac{1 - \prod_{j=1}^{n} (1 - a_j)^{w_j} \prod_{j=1}^{n} (1 - b_j)^{w_j}}{\prod_{j=1}^{n} c_j^{w_j} \prod_{j=1}^{n} d_j^{w_j}} \right].
\]

(4)

Here, \( W=(w_1, w_2, \ldots, w_n) \) is the weight vector of the \( \alpha_j(1, 2, \ldots, n) \), with \( w_j \in [0, 1], \sum_{j=1}^{n} w_j = 1 \). The comprehensive interval intuitionistic fuzzy number of each rescue base can be calculated by the interval intuitionistic fuzzy weighted arithmetic average operator.

**B. FUZZY CONVERSION OF DIFFERENT INDICATORS**

The key to the site selection decision is index assignment and weight calculation. From the description of AG600 site selection decision indicators, it can be seen that the land airport, water airport, water depth distribution, water area restriction, airspace restriction, wind, waves, and visibility indicators are quantitative indicators. Moreover, the support capability and application efficiency are qualitative indicators. Unlike the traditional method, which only relies on the subjective evaluation of experts, this paper proposes the idea of the quantitative transformation of quantitative indicators and qualitative indicators, so the site selection decision-making process is not divorced from the objective practical needs or the importance of expert experience.

**TABLE 2. The transformation of the linguistic fuzzy evaluation scale and interval intuitionistic fuzzy number.**

| Linguistic fuzzy evaluation scale | Interval intuitionistic fuzzy number |
|----------------------------------|-------------------------------------|
| \( a_1 \) excellent             | (0.9, 1)                            |
| \( a_1 \) very good              | (0.8, 0.9)                          |
| \( a_1 \) good                   | (0.7, 0.8)                          |
| \( a_1 \) upper                  | (0.6, 0.7)                          |
| \( a_1 \) middle                 | (0.5, 0.6)                          |
| \( a_1 \) lower                  | (0.4, 0.5)                          |
| \( a_1 \) bad                    | (0.2, 0.3)                          |
| \( a_1 \) very bad               | (0.1, 0.2)                          |
| \( a_1 \) poor                   | (0.0, 0.1)                          |

1) **TRANSFORMATION OF QUALITATIVE INDICATORS**

Inspired by [44], qualitative indicators are quantified and transformed by the method of the transformation of the language evaluation scale and interval intuitionistic fuzzy number. Assume that the language variables \( S = \{ s_i | i = 0, 1, 2, \ldots, k \} \) consist of odd elements, where \( k \) is an even number, \( s_i \) is the possible value of the language variable, the language scale of nine-level fuzzy evaluation \( a_i \in [0, k] \) is established, and for the interval intuitive fuzzy number transformation relationship, see Table 2. Further, \( \mu \) is the linguistic interval intuitive fuzzy membership degree, \( v \) is the linguistic interval intuitionistic fuzzy non-membership degree, and \( \pi \) is the linguistic interval intuitive fuzzy hesitancy degree.

2) **INTERVAL INTUITIONISTIC FUZZY TRANSFORMATION OF QUANTITATIVE INDEX**

It can be seen from AG600 site selection decision-making indicators that quantitative indicators include two types: interval number and real number. For interval number indicators, (5) and (6) are used to convert them into intuitionistic fuzzy numbers [44]. Then, combining expert experience and domain knowledge, we extend the intuitionistic fuzzy number to the interval intuitionistic fuzzy number.

Benefit indicators:

\[
    \alpha_i = (\mu_i, v_i) = \begin{cases} 
    \mu_i = \frac{d_i^U}{\max_{i=1,2,\ldots,n} \{d_i^U\}} \\
    v_i = 1 - \frac{\min_{i=1,2,\ldots,n} \{d_i^U\}}{d_i^U} 
    \end{cases}
\]

(5)

Cost indicators:

\[
    \alpha_i = (\mu_i, v_i) = \begin{cases} 
    \mu_i = \frac{a_i^U}{\min_{i=1,2,\ldots,n} \{a_i^U\}} \\
    v_i = 1 - \frac{\max_{i=1,2,\ldots,n} \{a_i^U\}}{a_i^U} 
    \end{cases}
\]

(6)
AG600 site selection indicators $u_1$ and $u_2$ are real indicators. Aiming at this kind of index, this paper proposes a method to transform the index by constructing the membership degree function. First, the membership degree and non-membership degree of the index are calculated according to the objective data of the base. On this basis, experts’ experience and domain knowledge are combined to expand the index into the interval intuitionistic fuzzy number. The membership function of indicators $u_1$ and $u_2$ are shown in (7) and (8). Owing to space limitation, the construction process of the membership function is not discussed in this paper.

$$U_1(x) = \begin{cases} 0, & 0 < x \leq 0.05 \\ 0.05 < x < 0.09, & 1, \end{cases} \quad \text{for } x \geq 0.09$$

$$U_2(x) = \begin{cases} 0, & 0 < x \leq 0.03 \\ 0.03 < x \leq 0.06, & 1, \end{cases} \quad \text{for } x \geq 0.06$$

IV. AG600 LOCATION SELECTION MODEL BASED ON THE IMPROVED INTERVAL INTUITIONISTIC FUZZY TOPSIS METHOD

The TOPSIS method is a common method to solve multi-attribute decision-making problems. The basic principle is to sort the evaluation objects by calculating how close the evaluation objects is to the positive ideal solutions and negative ideal solutions. In this paper, the similarity (1) of interval intuitionistic fuzzy sets is used to measure the proximity between the bases and the positive or negative ideal base [45].

Assume that there are $m$ selected bases for deploying AG600, and set up the marine base set $A = \{A_i | i = 1, 2, \ldots, m\}$. The index attribute set of the site selection decision $U = \{u_j | j = 1, 2, \ldots, n\}$, and the weight vector of the index $W = \{w_j | j = 1, 2, \ldots, n\}$, when $w_j \in [0, 1]$ ($j = 1, 2, \ldots, n$), $\sum_{j=1}^{n} w_j = 1$. $r_{ij} = \left(\left[\mu_{ij}^{L}, \mu_{ij}^{U}\right], \left[v_{ij}^{L}, v_{ij}^{U}\right]\right)$ is the evaluation value of base $A_i$ corresponding to decision attribute $U_j$, building decision matrix $R = \{r_{ij}\}_{m \times n}$ ($i = 1, 2, \ldots, n; j = 1, 2, \ldots, m$).

According to the basic principle of TOPSIS, the basic steps of the AG600 location decision are given as follows:

Step 1: Standardize the decision matrix. As there are different measurement standards and different types of attributes, it is necessary to value all attributes using a unified standard before making a decision so as to eliminate the differences in the dimension, unit, and type of each attribute. Generally, we convert the cost type into the benefit, and the standardization process is as follows:

$$\tilde{r}_{ij} = \left\{ \left[\mu_{ij}^{L}, \mu_{ij}^{U}\right], \left[v_{ij}^{L}, v_{ij}^{U}\right]\right\}$$

Benefit attribute

Cost attribute

Step 2: Determine the positive ideal plan $(A^+)\text{ and negative ideal plan } (A^-)$ as

$$\begin{align*}
A^+ &= \left\{ r_1^+, r_2^+, \ldots, r_n^+ \right\}, \\
A^- &= \left\{ r_1^-, r_2^-, \ldots, r_n^- \right\}.
\end{align*}$$

where

$$\begin{align*}
r_j^+ &= \left[\max \left[\mu_{ij}^{L}, \mu_{ij}^{L'}, \ldots, \mu_{mj}^{L}\right], \max \left[\mu_{ij}^{U}, \mu_{ij}^{U'}, \ldots, \mu_{mj}^{U}\right]\right], \\
&\left[\min \left[v_{ij}^{L}, v_{ij}^{L'}, \ldots, v_{mj}^{L}\right], \min \left[v_{ij}^{U}, v_{ij}^{U'}, \ldots, v_{mj}^{U}\right]\right],
\end{align*}$$

$$\begin{align*}
r_j^- &= \left[\min \left[\mu_{ij}^{L}, \mu_{ij}^{L'}, \ldots, \mu_{mj}^{L}\right], \min \left[\mu_{ij}^{U}, \mu_{ij}^{U'}, \ldots, \mu_{mj}^{U}\right]\right], \\
&\left[\max \left[v_{ij}^{L}, v_{ij}^{L'}, \ldots, v_{mj}^{L}\right], \max \left[v_{ij}^{U}, v_{ij}^{U'}, \ldots, v_{mj}^{U}\right]\right].
\end{align*}$$

Step 3: According to the decision matrix, $w_j, j = 1, 2, \ldots, m$, as the objective weight of each attribute, is obtained by (2) and (3).

Step 4: Using (4), calculate the synthetic attribute interval intuitionistic fuzzy number of $A_i, A^+, \text{ and } A^-$. 

$$\begin{align*}
\alpha_i &= \left(\left[\mu_{ij}^{L}, \mu_{ij}^{U}\right], \left[v_{ij}^{L}, v_{ij}^{U}\right]\right) (i = 1, 2, \ldots, m); \\
\alpha^+ &= \left(\left[\mu_{ij}^{L}, \mu_{ij}^{U}\right], \left[v_{ij}^{L}, v_{ij}^{U}\right]\right); \\
\alpha^- &= \left(\left[\mu_{ij}^{L}, \mu_{ij}^{U}\right], \left[v_{ij}^{L}, v_{ij}^{U}\right]\right).
\end{align*}$$

Step 5: Based on the results of Step 4, (1) is improved to simplify the calculation process, from requiring the similarity of each attribute to only calculating the similarity of the synthetic attribute interval intuitionistic fuzzy number $A_i, A^+, \text{ and } A^-$. Calculate the similarity of $A_i, A^+$ as well as $A_i$ and $A^-$ separately by (11) and (12), as shown at the bottom of the page.

Step 6: Calculate the similarity of $A_i$ by (13):

$$S(A_i, A^+) = \frac{S(A_i, A^+)}{S(A_i, A^+) + S(A_i, A^-)}, i = 1, 2, \ldots, m.$$

Step 7: Determine the order of $A_i$ according to the size of $S(A_i) (i = 1, 2, \ldots, n)$. $A_k$ The larger $A$ is, the more suitable the base is for deploying AG600.
The transformation process is not discussed here. The interval be standardized through (9). Owing to the space limitation, u converted into IVIFs through (5) and (6). Index The rest of the indicators are interval numbers, which are converted into IVIFs by the language fuzzy conversion method. u real indices, which are converted into IVIFs through (7) known from the AG600 site selection indicator system U Mischievous Island, Fiery Cross Island, Subi Island. It is the scheme set A deployment of AG600, As shown in Fig. 1. We set up the South China Sea as the research area. ag600 deployment bases to be evaluated. (a) Yongxing Island (b) Meiji Island (c) Fiery Cross Island (d) Subi Island.

V. CASE STUDY
This paper takes the South China Sea as the research space and chooses Yongxing Island, Mischief Island, Fiery Cross Island, and Subi Island as the candidate bases for the deployment of AG600. As shown in Fig. 1. We set up the scheme set A = {A1, A2, A3, A4} = {Yongxing Island, Mischief Island, Fiery Cross Island, Subi Island}. It is known from the AG600 site selection indicator system U = {u1, u2, u3, u4, u5, u6, u7, u8, u9, u10} that index u1, u2 are real indices, which are converted into IVIFs through (7) and (8). Indices u3, u5 are language variables, which are converted into IVIFs by the language fuzzy conversion method. The rest of the indicators are interval numbers, which are converted into IVIFs through (5) and (6). Index u4, u7 are cost indices, while others are the benefit indicator, which can be standardized through (9). Owing to the space limitation, the transformation process is not discussed here. The interval intuitionistic fuzzy value of indices corresponding to the transformed islands is shown in Table 3. According to Table 3, the interval intuitionistic fuzzy matrix \( R = (r_{ij})_{m \times n} \) and \( r_{ij} = \left( \left[ \mu_{ij}^{U}, \nu_{ij}^{U} \right], \left[ \mu_{ij}^{L}, \nu_{ij}^{L} \right] \right) \) is established.

Identify the positive ideal scheme \( A^+ = \{ \tilde{r}_1, \tilde{r}_2, \ldots, \tilde{r}_n \} \) and negative ideal scheme \( A^- = \{ \tilde{r}_1, \tilde{r}_2, \ldots, \tilde{r}_n \} \) according to the interval intuition fuzzy matrix \( R = (r_{ij})_{m \times n} \) (Table 4).

Equations (2) and (3) are used to calculate the weight \( w_j \), \( j = 1, 2, \ldots, m \) of each attribute \( (u_j) \) (Table 5).

In order to focus on the contribution of all attributes to site selection decision, (4) is used to calculate the comprehensive attribute interval intuitionistic fuzzy value of \( A_i, A^+, \) and \( A^- \).

\[
\alpha_1 = (0.63, 0.75, [0.09, 0.19]);
\]
\[
\alpha_2 = (0.66, 0.77, [0.09, 0.16]);
\]
\[
\alpha_3 = (0.63, 0.74, [0.10, 0.20]);
\]
\[
\alpha_4 = (0.64, 0.75, [0.10, 0.20]);
\]
\[
\alpha^+ = (0.79, 0.88, [0.02, 0.08]);
\]
\[
\alpha^- = (0.44, 0.54, [0.25, 0.35]);
\]

Based on the comprehensive attribute interval intuitionistic fuzzy value of \( A_i, A^+, \) and \( A^- \), by (11) and (12), we calculate the similarity of \( A_i \) and \( A^+ \) as well as \( A_i \) and \( A^- \), respectively.

\[
S(\tilde{A}_i, A^+) = 0.798, S(\tilde{A}_i, A^-) = 0.698;
\]
\[
S(\tilde{A}_2, A^+) = 0.822, S(\tilde{A}_2, A^-) = 0.677;
\]
\[
S(\tilde{A}_3, A^+) = 0.780, S(\tilde{A}_3, A^-) = 0.715;
\]
\[
S(\tilde{A}_4, A^+) = 0.791, S(\tilde{A}_4, A^-) = 0.705;
\]

We use (13) to calculate the relative similarity \( S(A_i) \) of \( A_i \):

\[
S(\tilde{A}_1) = 0.533; S(\tilde{A}_2) = 0.548;
\]
\[
S(\tilde{A}_3) = 0.522; S(\tilde{A}_4) = 0.529.
\]
The larger the value of \( S(A_i) \) is, the more suitable the island is for AG600 deployment. The AG600 deployment priorities are as follows: \( A_2 \succ A_1 \succ A_4 \succ A_3 \).

In order to verify the accuracy and reliability of the AG600 maritime base location decision model proposed in this paper, the score function method in [30] and the projection method in [46] are used to calculate and evaluate this case, and the results are shown in Table 6.

Table 6 shows that the ranking results of maritime rescue bases obtained by the evaluation methods in [30] and [46] are consistent with those obtained by the AG600 rescue base location method in this paper. However, it is not difficult to find from the data that compared with the other two methods, the result calculated by the method adopted in this paper is more identifiable. According to the ranking results and the analysis of the actual situation of the South China Sea islands, Meiji Island and Yongxing Island are more suitable than Fiery Cross Island and Yongshu Island. Apart from the islands’ superior natural conditions, the construction and development degree of the islands is also the main determinant factor. Meiji Island is more suitable for the deployment of AG600 than Yongxing Island for two main reasons. First, Meiji Island has the largest land area, which can provide a guarantee for the subsequent construction of the airport and other facilities on the island. Second, there is a lagoon in Meiji Island that meets the construction conditions of an AG600 amphibious aircraft water airport. The central lagoon of Yongxing Island has dried up. Although there is a large ship wharf around the island, the frequent traffic of ships seriously interferes with the takeoff, landing, and berthing of AG600, which is not suitable for the construction of the water airport. According to the conclusions, through consultation with maritime rescue experts and first-line rescue personnel, it is agreed that the results obtained by the location model are consistent with the actual airport construction needs and can be applied to the intelligent location decision of the AG600 marine rescue base.

Considering the possible inversion of ranking, SPOTIS method and the method presented in this paper are used for comparative analysis. The SPOTIS method is one of the most recent as it was introduced in 2020 [47], [48]. This method was created with being rank reversal phenomenon resistant. The method involve following steps.

**Step 1:** Define the bounds of the problem – min and max bounds of classical MCDM problem must be defined to transform MCDM problem form ill-defined to well-defined.

\[
S_{\min} \leq x_1 \leq S_{\max}
\]  

where, \( n \) – criterion number, \( x_1 \) – min bound, \( x_2 \) – max bound

**Step 2:** Define the ideal solution point – define vector which includes maximum or minimum from bounds for specific criterion depending on criterion type. For profit type, the max value should be taken, for cost type, min value.

\[
S_{\min} \leq x_1 \leq S_{\max}
\]  

**Step 3:** Compute normalized distance matrix – for each alternative \( i \) (i=1,2,…,M), compute its normalized...
distance with respect to ideal solution for each criteria \(cj\) (j=1,2,...,N).

\[
d_{ij} = \frac{|A_{ij} - S_j^*|}{|S_j^{max} - S_j^{min}|},
\]

(16)

**Step 4:** Compute normalized averaged distance – for each criteria \(cj\) (j=1,2,...,N) take into account its weight and calculate final preference by executing following equation.

\[
\tilde{p}_j = \frac{1}{N} \sum_{j=1}^{N} w_j d_{ij},
\]

(17)

**Step 5:** Rank criteria by preference – values should be ranked in ascending order.

Substitute the data into the above steps, and the calculated result is \(A_1 = 0.656; A_2 = 0.581; A_3 = 0.693; A_4 = 0.691\). The AG600 deployment priorities are as follows:

\(A_2 > A_1 > A_3 > A_4\)

Through comparative analysis of the calculation results of SOPTIS method and the method in this paper, it can be seen that \(A_2\) and \(A_4\) rankings of the two methods are different. Combined with the actual situation of the islands and reefs in the South China Sea and the analysis of the objective actual data, it can be seen that the index value of visibility has a large magnitude, which has a great influence on the ranking results without standardization. The change of wind and wave indices also has a certain influence on the ranking results. The WS coefficient is used to conduct sensitivity analysis on the rankings of the two methods, and the obtained value is 0.908. It can be seen from the calculation results that although the rankings provided by the two survey methods are slightly different, the rankings of the two methods have a high degree of convergence. On the other hand, the validity of the method proposed in this paper can be verified. At the same time, it can be concluded that the problem of inversion of ranking can be ignored for the island location of AG600.

**VI. CONCLUSION**

In this paper, the AG600 maritime rescue base location decision with a completely unknown attribute weight has been taken as the research background, and the AG600 location decision model based on interval intuitionistic fuzzy TOPSIS method has been constructed. The location index system of the AG600 maritime rescue base has been proposed and determined for the first time. According to the different index types, based on the interval intuitionistic fuzzy theory, the distinction fuzzy transformation method of index has been proposed innovatively. By combining it with the traditional subjective experience assignment method, the interval intuitionistic fuzzy number of the index can be determined more scientifically and reasonably. In the process of index weighting, the interval intuitionistic fuzzy entropy method is used to calculate the weight of each index more objectively. In the process of the evaluation of the islands, the comprehensive interval intuitionistic fuzzy number of each rescue base is calculated by the interval intuitionistic fuzzy weighted arithmetic average operator. Then, the approximate degree between the islands and the ideal solution is judged by the interval intuitionistic fuzzy similarity; the calculation process is simplified, and the decision-making efficiency is improved. Finally, the AG600 maritime rescue base location model has been used to evaluate the islands for the deployment of AG600 in the South China Sea, and the evaluation result has been verified to be correct and reliable by comparing with the score function method and projection method. The results obtained by the three methods are identical. Finally, SPOTIS method was used to verify the inversion problem, and WS coefficient was used to analyze the sensitivity of the two, which verified the effectiveness of the method proposed in this paper, and it was concluded that the inversion problem could be ignored for AG600 island site selection. Through investigation and consultation with rescue experts and first responders at sea, we have agreed that the results obtained by this method are consistent with the actual situation and can provide technical support and scientific guidance for the future deployment of AG600 at sea.

With the continuous construction and improvement of maritime island bases and the continuous development of maritime shipping, the joint rescue of rescue ships, rescue helicopters and AG600 and other rescue equipment is the development direction of maritime rescue in the future. Therefore, in the next step, a more perfect index system and evaluation model can be determined by comprehensively considering the trend of various rescue equipment and island construction, so as to realize the site selection decision of joint deployment of various equipment.

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