Research Article

Method for Pythagorean Interval 2-Tuple Linguistic Multiattribute Group Decision Making and Its Application to the Ship Navigation Environment Safety Assessment

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In this paper, some fundamental theories of the Pythagorean interval 2-tuple linguistic numbers (PI2TLNs) combined with the EDAS (evaluation based on distance from average solution) method are proposed. Firstly, we introduced the original concepts of Pythagorean interval 2-tuple linguistic sets (PI2TLSs), and two aggregation operators of PI2TLN were also introduced. Then, the steps of the EDAS method were described briefly. Moreover, the PI2TLN-EDAS model was provided to address the multiattribute group decision-making (MAGDM) problem, and calculation steps were deduced in detail. The effectiveness of the method was illustrated by taking the ship navigation environment safety assessment as an example. Finally, we conducted comparative analysis between PI2TLN-EDAS method and Pythagorean interval 2-tuple linguistic weighted averaging (PI2TLWA) operator/Pythagorean interval 2-tuple linguistic weighted geometric (PI2TLWG) operator.

1. Introduction

The EDAS method proposed by Ghorabae et al. [1] is an evaluation method that calculates the positive and negative distances between each alternative and the average alternative. Different methods are used to deal with the multiattribute decision-making (MADM) problems where the decision information is a certain number [2–7]. Similar to the VIKOR method [8–12], TOPSIS method [13–17], and GRA method [18], the EDAS method is effective when conflicting criteria are present in the MADM issues. Aiming at the case where the decision information is a definite number [19–21], the EDAS method is proposed. Based on this idea, many scholars extended the EDAS method to the fuzzy set environment. For example, Kahraman et al. [22] extended the classical EDAS method to ordinary fuzzy sets. Liang et al. [23] used the EDAS-ELECTRE comprehensive evaluation method to evaluate the clean production performance of the gold mining enterprises. Jiang et al. [24] built the EDAS method based on cumulative prospect theory for MAGDM under picture fuzzy environment. Peng et al.

[25] applied the EDAS method to solve the interval value fuzzy soft decision problem. Huang et al. [26] defined an enhancement EDAS method based on prospect theory. Wei et al. [27] built the EDAS method for probabilistic linguistic MAGDM. Lei et al. [28] proposed the PDHL-EDAS method for MAGDM.

In the process of decision making, there is a wide range of ambiguity and uncertainty [29–33] such as classical fuzzy set [34], intuitionistic fuzzy sets (IFSs) [35–41], probabilistic hesitant fuzzy set [42–47], probabilistic linguistic sets [48–53], and probabilistic double hierarchy linguistic sets [54–56]. Yager [57] put forward the concept of Pythagorean fuzzy set (PFSs). Zhang [58] defined the accuracy function and new aggregation operator of Pythagorean fuzzy numbers (PFNs) and proposed the similarity measurement method of PFNs based on the method of similarity measure. Zeng et al. [59] combined the distance measure with the PFS and proposed the Pythagorean ordered weighted, average weighted, and average distance operators. Garg [60] introduced the statistical concept of confidence level into the Pythagorean fuzzy set. To better provide decision

information in a form that is consistent with the language habits of decision makers, Huang and Wei [61] defined the Pythagorean 2-tuple linguistic fuzzy sets (P2TLSs) and introduced its related properties. The concept of Pythagorean interval 2-tuple linguistic sets (PI2TLSs) first appeared [61] on the basis of PFSS [62] and 2-tuple linguistic information [63].

Because the EDAS method is an effective MADM method and Pythagorean interval 2-tuple linguistic fuzzy set has the characteristics of two-stage description, it can relatively contain more decision-making information and describe objective facts more comprehensively and accurately. Based on the advantages of both, this paper attempts to extend the EDAS method to decision environment of Pythagorean interval 2-tuple linguistic fuzzy set (PI2TLS) and proposes a Pythagorean interval 2-tuple linguistic MADM model based on the EDAS method.

The rest of this paper is arranged as follows. In Section 2, some fundamental definitions of Pythagorean interval 2-tuple linguistic numbers (PI2TLNs) are given. In Section 3, the EDAS method is extended using PI2TLNs. In Section 4, a case study for evaluating the ship navigation environment safety is given. Section 5 gives some conclusions.

2. Preliminaries

2.1. Pythagorean Interval 2-Tuple Linguistic Sets. The concept of Pythagorean interval 2-tuple linguistic sets (PI2TLSs) first appeared [61] on the basis of PFSS [62] and 2-tuple linguistic information [63].

Definition 1 (see [61]). In a PI2TLS, A in the theoretical field X is defined as follows:

$$A = \{[(\psi_{(x)}, \alpha_{(x)}), (\delta_{(x)}, \beta_{(x)})], (u_A(x), v_A(x)), x \in X\}, \quad (1)$$

where $[(\psi_{(x)}, \alpha_{(x)}), (\delta_{(x)}, \beta_{(x)})]$ is an interval 2-tuple linguistic variable, $\psi_{(x)}, \delta_{(x)} \in S = \{S_0, S_1, \dots, S_T\}$, S is a linguistic term set, and $\alpha_{(x)}, \beta_{(x)} \in [-0.5, 0.5]$, $u_A(x), v_A(x) \in [0, 1]$ represent the degree of membership and degree of non-membership of the element x to an interval 2-tuple linguistic $[(\psi_{(x)}, \alpha_{(x)}), (\delta_{(x)}, \beta_{(x)})]$ and meet the condition $0 \leq u_A(x)^2 + v_A(x)^2 \leq 1 \in [0, 1]$.

For convenience, $A = \langle [(\psi_A, \alpha_A), (\delta_A, \beta_A)], (u_A, v_A) \rangle$ can be called a Pythagorean interval 2-tuple linguistic number (PI2TLN).

Definition 2 (see [61]). For a PI2TLN $\tilde{a} = \langle [(\psi_a, \alpha_a), (\delta_a, \beta_a)], (u_a, v_a) \rangle$, its score function is

$$Sf(\tilde{a}) = \Delta \left(\frac{\Delta^{-1}(\psi_a, \alpha_a) + \Delta^{-1}(\delta_a, \beta_a)}{2} \times \frac{1 + (u_a)^2 - (v_a)^2}{2} \right). \quad (2)$$

Definition 3 (see [61]). For a PI2TLN $\tilde{a} = \langle [(\psi_a, \alpha_a), (\delta_a, \beta_a)], (u_a, v_a) \rangle$, its accuracy function is

$$Af(\tilde{a}) = \Delta \left(\frac{\Delta^{-1}(\psi_a, \alpha_a) + \Delta^{-1}(\delta_a, \beta_a)}{2} \times \frac{(u_a)^2 + (v_a)^2}{2} \right). \quad (3)$$

Definition 4 (see [61]). For two PI2TLNs $\tilde{a}_1 = \langle [(\psi_{a_1}, \alpha_{a_1}), (\delta_{a_1}, \beta_{a_1})], (u_{a_1}, v_{a_1}) \rangle$ and $\tilde{a}_2 = \langle [(\psi_{a_2}, \alpha_{a_2}), (\delta_{a_2}, \beta_{a_2})], (u_{a_2}, v_{a_2}) \rangle$, respectively, the scores of $\tilde{a}_1$ and $\tilde{a}_2$ are $Sf(\tilde{a}_1) = \Delta(\Delta^{-1}(\psi_{a_1}, \alpha_{a_1}) + \Delta^{-1}(\delta_{a_1}, \beta_{a_1})/2 \times 1 + (u_{a_1})^2 - (v_{a_1})^2/2)$ and $Sf(\tilde{a}_2) = \Delta(\Delta^{-1}(\psi_{a_2}, \alpha_{a_2}) + \Delta^{-1}(\delta_{a_2}, \beta_{a_2})/2 \times 1 + (u_{a_2})^2 - (v_{a_2})^2/2)$, and let $Af(\tilde{a}_1) = \Delta(\Delta^{-1}(\psi_{a_1}, \alpha_{a_1}) + \Delta^{-1}(\delta_{a_1}, \beta_{a_1})/2 \times (u_{a_1})^2 + (v_{a_1})^2/2)$ and $Af(\tilde{a}_2) = \Delta(\Delta^{-1}(\psi_{a_2}, \alpha_{a_2}) + \Delta^{-1}(\delta_{a_2}, \beta_{a_2})/2 \times (u_{a_2})^2 + (v_{a_2})^2/2)$ be the accuracy degrees of $\tilde{a}_1$ and $\tilde{a}_2$; then, some operational laws of PI2TLNs are defined as follows:

- (1) If $Sf(\tilde{a}_1) < Sf(\tilde{a}_2)$, $\tilde{a}_1 < \tilde{a}_2$.
- (2) If $Sf(\tilde{a}_1) > Sf(\tilde{a}_2)$, $\tilde{a}_1 > \tilde{a}_2$.
- (3) If $Sf(\tilde{a}_1) = Sf(\tilde{a}_2)$, $Af(\tilde{a}_1) < Af(\tilde{a}_2)$, then $\tilde{a}_1 < \tilde{a}_2$.
- (4) If $Sf(\tilde{a}_1) = Sf(\tilde{a}_2)$, $Af(\tilde{a}_1) > Af(\tilde{a}_2)$, then $\tilde{a}_1 > \tilde{a}_2$.
- (5) If $Sf(\tilde{a}_1) = Sf(\tilde{a}_2)$, $Af(\tilde{a}_1) = Af(\tilde{a}_2)$, then $\tilde{a}_1 = \tilde{a}_2$.

Definition 5 (see [61]). For two PI2TLNs $\tilde{a}_1 = \langle [(\psi_{a_1}, \alpha_{a_1}), (\delta_{a_1}, \beta_{a_1})], (u_{a_1}, v_{a_1}) \rangle$ and $\tilde{a}_2 = \langle [(\psi_{a_2}, \alpha_{a_2}), (\delta_{a_2}, \beta_{a_2})], (u_{a_2}, v_{a_2}) \rangle$, the normalized Hamming distance (H_d) between $\tilde{a}_1$ and $\tilde{a}_2$ is defined as

$$H_d(\tilde{a}_1, \tilde{a}_2) = \frac{1}{4L} \left[\left| \left(1 + (u_{a_1})^2 - (v_{a_1})^2 \right) \cdot (\Delta^{-1}(\psi_{a_1}, \alpha_{a_1}) + \Delta^{-1}(\delta_{a_1}, \beta_{a_1})) - \left(1 + (u_{a_2})^2 - (v_{a_2})^2 \right) \cdot (\Delta^{-1}(\psi_{a_2}, \alpha_{a_2}) + \Delta^{-1}(\delta_{a_2}, \beta_{a_2})) \right| \right], \quad (4)$$

where L represents the length of the language scale. It is a numerical value.

Definition 6 (see [61]). For two PI2TLNs $\tilde{a}_1 = \langle [(\psi_{a_1}, \alpha_{a_1}), (\delta_{a_1}, \beta_{a_1})], (u_{a_1}, v_{a_1}) \rangle$ and $\tilde{a}_2 = \langle [(\psi_{a_2}, \alpha_{a_2}), (\delta_{a_2}, \beta_{a_2})], (u_{a_2}, v_{a_2}) \rangle$, then

$$\begin{aligned}\tilde{a}_1 \oplus \tilde{a}_2 &= \left\langle \left[\Delta(\Delta^{-1}(\psi_{a_1}, \alpha_{a_1}) + \Delta^{-1}(\psi_{a_2}, \alpha_{a_2})), \Delta(\Delta^{-1}(\delta_{a_1}, \beta_{a_1}) + \Delta^{-1}(\delta_{a_2}, \beta_{a_2})) \right], \left(\sqrt{(u_{a_1})^2 + (u_{a_2})^2 - (u_{a_1})^2 (u_{a_2})^2}, v_{a_1} v_{a_2} \right) \right\rangle; \\ \tilde{a}_1 \otimes \tilde{a}_2 &= \left\langle \left[\Delta(\Delta^{-1}(\psi_{a_1}, \alpha_{a_1}) \times \Delta^{-1}(\psi_{a_2}, \alpha_{a_2})), \Delta(\Delta^{-1}(\delta_{a_1}, \beta_{a_1}) \times \Delta^{-1}(\delta_{a_2}, \beta_{a_2})) \right], \left(u_{a_1} u_{a_2}, \sqrt{(v_{a_1})^2 + (v_{a_2})^2 - (v_{a_1})^2 (v_{a_2})^2} \right) \right\rangle; \\ \lambda \tilde{a}_1 &= \left\langle \left[\Delta(\lambda \Delta^{-1}(\psi_{a_1}, \alpha_{a_1})), \Delta(\lambda \Delta^{-1}(\delta_{a_1}, \beta_{a_1})) \right], \left(\sqrt{1 - (1 - (u_{a_1})^2)^\lambda}, (v_{a_1})^\lambda \right) \right\rangle; \\ (\tilde{a}_1)^\lambda &= \left\langle \left[\Delta((\Delta^{-1}(\psi_{a_1}, \alpha_{a_1}))^\lambda), \Delta((\Delta^{-1}(\delta_{a_1}, \beta_{a_1}))^\lambda) \right], \left((u_{a_1})^\lambda, \sqrt{1 - (1 - (v_{a_1})^2)^\lambda} \right) \right\rangle.\end{aligned}\quad (5)$$

2.2. Pythagorean Interval 2-Tuple Linguistic Arithmetic Aggregation Operators. In this section, the PI2TLWA operator and PI2TLWG operator are introduced.

Definition 7 (see [64]). For $\tilde{a}_j = \langle [(\psi_{a_j}, \alpha_{a_j}), (\delta_{a_j}, \beta_{a_j})], (u_{a_j}, v_{a_j}) \rangle$ ($j = 1, 2, \dots, n$) is a collection of PI2TLNs. PI2TLWA operator is defined as

$$\begin{aligned}\text{PI2TLWA}_\omega(\tilde{a}_1, \tilde{a}_2, \dots, \tilde{a}_n) &= \bigoplus_{j=1}^n (\omega_j \tilde{a}_j) \\ &= \left\langle \left[\Delta\left(\sum_{j=1}^n \omega_j \Delta^{-1}(\psi_{a_j}, \alpha_{a_j})\right), \Delta\left(\sum_{j=1}^n \omega_j \Delta^{-1}(\delta_{a_j}, \beta_{a_j})\right) \right], \left(\sqrt{1 - \prod_{j=1}^n (1 - (u_{a_j})^2)^{\omega_j}}, \prod_{j=1}^n (v_{a_j})^{\omega_j} \right) \right\rangle,\end{aligned}\quad (6)$$

where $\omega = (\omega_1, \omega_2, \dots, \omega_n)^T$ is the weight vector of $\tilde{a}_j$ ($j = 1, 2, \dots, n$) and $\omega_j > 0, \sum_{j=1}^n \omega_j = 1$.

Definition 8 (see [31]). For $\tilde{a}_j = \langle [(\psi_{a_j}, \alpha_{a_j}), (\delta_{a_j}, \beta_{a_j})], (u_{a_j}, v_{a_j}) \rangle$ ($j = 1, 2, \dots, n$) is a collection of PI2TLNs. PI2TLWG operator is defined as

$$\begin{aligned}\text{PI2TLWG}_\omega(\tilde{a}_1, \tilde{a}_2, \dots, \tilde{a}_n) &= \bigotimes_{j=1}^n (\omega_j \tilde{a}_j) \\ &= \left\langle \left[\Delta\left(\prod_{j=1}^n \Delta^{-1}(\psi_{a_j}, \alpha_{a_j})^{\omega_j}\right), \Delta\left(\prod_{j=1}^n \Delta^{-1}(\delta_{a_j}, \beta_{a_j})^{\omega_j}\right) \right], \left(\prod_{j=1}^n (u_{a_j})^{\omega_j}, \sqrt{1 - \prod_{j=1}^n (1 - (v_{a_j})^2)^{\omega_j}} \right) \right\rangle,\end{aligned}\quad (7)$$

where $\omega = (\omega_1, \omega_2, \dots, \omega_n)^T$ is the weight vector of $\tilde{a}_j$ ($j = 1, 2, \dots, n$) and $\omega_j > 0, \sum_{j=1}^n \omega_j = 1$.

3. EDAS Method for MAGDM with PI2TLNs

Let $P = \{P_1, P_2, \dots, P_m\}$ be a solution set, $\sigma = \{\sigma_1, \sigma_2, \dots, \sigma_n\}$ be an evaluation attribute set, and $D = \{D_1, D_2, \dots, D_k\}$ be an expert set. $\{\omega_1, \omega_2, \dots, \omega_k\}$ and $\{\omega_1, \omega_2, \dots, \omega_n\}$ are,

respectively, the expert's weighting vector and attribute's weighting vector which satisfy $\omega_t \in [0, 1], \omega_j \in [0, 1]$ and $\sum_{t=1}^k \omega_t = 1, \sum_{j=1}^n \omega_j = 1$. The calculation steps of this method are as follows:

Step 1. A DM group is constructed to select the best attribute for the performance measurement of the alternative, and the evaluation matrix $T^{(k)} = (t_{ij}^{(k)})_{m \times n}$ of each decision maker with PI2TLNs is finally formed:

$$T^{(k)} = [t_{ij}^k]_{m \times n} = \begin{bmatrix} t_{11}^k & t_{12}^k & \dots & t_{1n}^k \\ t_{21}^k & t_{22}^k & \dots & t_{2n}^k \\ \vdots & \vdots & \vdots & \vdots \\ t_{m1}^k & t_{m2}^k & \dots & t_{mn}^k \end{bmatrix}. \quad (8)$$

Step 2. Use PI2TLWA operator or PI2TLWG operator to obtain the group evaluation matrix $T = (t_{ij})_{m \times n}$:

$$T = [tE]_{m \times n} = \begin{bmatrix} t_{11} & t_{12} & \dots & t_{1n} \\ t_{21} & t_{22} & \dots & t_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ t_{m1} & t_{m2} & \dots & t_{mn} \end{bmatrix},$$

$$t_{ij} = \bigoplus_{t=1}^k t_{ij}^k = PI2TLWA(t_{ij}^1, t_{ij}^2, \dots, t_{ij}^k) \quad (9)$$

$$= \left\langle \begin{bmatrix} \Delta \left(\sum_{t=1}^k \omega_t \Delta^{-1} \left(\psi_{g_{ij}}^{(t)}, \alpha_{g_{ij}}^{(t)} \right) \right) \\ \Delta \left(\sum_{t=1}^k \omega_t \Delta^{-1} \left(\delta_{g_{ij}}^{(t)}, \beta_{g_{ij}}^{(t)} \right) \right) \end{bmatrix}, \left(\sqrt{1 - \prod_{t=1}^k \left(1 - \left(u_{g_{ij}}^{(t)} \right)^2 \right)^{\omega_t}}, \prod_{t=1}^k \left(v_{g_{ij}}^{(t)} \right)^{\omega_t} \right) \right\rangle,$$

or

$$t_{ij} = \bigotimes_{t=1}^k t_{ij}^k = P2TLWG(t_{ij}^1, t_{ij}^2, \dots, t_{ij}^k) \quad (10)$$

$$= \left\langle \begin{bmatrix} \Delta \left(\sum_{t=1}^k \Delta^{-1} \left(\psi_{g_{ij}}^{(t)}, \alpha_{g_{ij}}^{(t)} \right)^{\omega_t} \right) \\ \Delta \left(\sum_{t=1}^k \Delta^{-1} \left(\delta_{g_{ij}}^{(t)}, \beta_{g_{ij}}^{(t)} \right)^{\omega_t} \right) \end{bmatrix}, \left(\prod_{t=1}^k \left(u_{g_{ij}}^{(t)} \right)^{\omega_t} \sqrt{1 - \prod_{t=1}^k \left(1 - \left(v_{g_{ij}}^{(t)} \right)^2 \right)^{\omega_t}} \right) \right\rangle.$$

Step 3. Calculate AV:

According to Definition 6,

$$AV = [AV_j]_{1 \times n} = \left[\frac{\sum_{i=1}^m t_{ij}}{m} \right]_{1 \times n}. \quad (11)$$

$$\sum_{i=1}^m t_{ij} = \left\langle \begin{bmatrix} \Delta \left(\sum_{i=1}^m \Delta^{-1} \left(\psi_{g_{ij}}, \alpha_{g_{ij}} \right) \right) \\ \Delta \left(\sum_{i=1}^m \Delta^{-1} \left(\delta_{g_{ij}}, \beta_{g_{ij}} \right) \right) \end{bmatrix}, \left(\sqrt{1 - \prod_{i=1}^m \left(1 - \left(u_{g_{ij}} \right)^2 \right)}, \prod_{i=1}^m \left(v_{g_{ij}} \right) \right) \right\rangle. \quad (12)$$

Thus,

$$\begin{aligned}
AV &= [AV_j]_{1 \times n} = \left[\frac{\sum_{i=1}^m t_{ij}}{m} \right]_{1 \times n} \\
&= \left\langle \begin{bmatrix} \Delta \left(\sum_{i=1}^m \frac{1}{m} \Delta^{-1}(\psi_{g_{ij}}, \alpha_{g_{ij}}) \right) \\ \Delta \left(\sum_{i=1}^m \frac{1}{m} \Delta^{-1}(\delta_{g_{ij}}, \beta_{g_{ij}}) \right) \end{bmatrix}, \left(\sqrt{1 - \prod_{i=1}^m \left(1 - (u_{g_{ij}})^2 \right)^{1/m}}, \prod_{i=1}^m (v_{g_{ij}})^{1/m} \right) \right\rangle. \quad (13)
\end{aligned}$$

Step 4. According to AV , calculate the values of PDA and NDA depending on the type of attribute.

$$PDA_{ij} = [PDA_{ij}]_{m \times n} = \frac{\max(0, (t_{ij} - AV_j))}{AV_j}, \quad (14)$$

$$NDA_{ij} = [NDA_{ij}]_{m \times n} = \frac{\max(0, (AV_j - t_{ij}))}{AV_j}. \quad (15)$$

To facilitate calculation, the PI2TLNs' scoring function proposed in Definition 2 is used to calculate the PDA and NDA values as follows:

$$\begin{aligned}
PDA_{ij} &= [PDA_{ij}]_{m \times n} = \frac{\max(0, (s(t_{ij}) - s(AV_j)))}{s(AV_j)}, \\
NDA_{ij} &= [NDA_{ij}]_{m \times n} = \frac{\max(0, (s(AV_j) - s(t_{ij})))}{s(AV_j)}. \quad (16)
\end{aligned}$$

Step 5. Calculate weighting distance SP_i and SN_i .

$$\begin{aligned}
SP_i &= \sum_{j=1}^n \omega_j PDA_{ij}, \\
SN_i &= \sum_{j=1}^n \omega_j NDA_{ij}. \quad (17)
\end{aligned}$$

Step 6. Normalize the calculating results of the following equation:

$$\begin{aligned}
NSP_i &= \frac{SP_i}{\max(SP_i)}, \\
NSN_i &= 1 - \frac{SN_i}{\max(SN_i)}. \quad (18)
\end{aligned}$$

Step 7. Calculate the values of appraisal score (AS).

$$AS_i = \frac{1}{2} (NSP_i + NSN_i). \quad (19)$$

Step 8. All alternatives are ranked according to their final evaluation value.

4. Numerical Example

In recent years, due to the increase in ship types, larger ships, faster speeds, congested routes, and more bridges and port facilities, the navigation environment has undergone great changes and become more and more complex, but operators must operate in a certain environment. Based on the severe changes around sailing environment, the difficulty for operation becomes harder and harder for operators to finish tasks safely and efficiently under this environment. More mistakes will occur because the pressure of the operators becomes heavier and heavier. To prevent and reduce occurrence of accidents and to make safe and efficient transportation on the sea, not only the quality of operators should be improved and the performance and management of the ship should be improved but also the sailing environment should be improved. The improvement of environment is based on systematic analysis and evaluation of the environment, so we have to understand what the danger elements are in the sailing and what level the danger has reached, so as to take pointed measure to improve the environment. According to the relevant conclusions, ship operation simulation results, and domestic and foreign expert consultation, this paper sets the risk evaluation level for each evaluation target and uses the PI2TLN-EDAS method to evaluate the safety of the ship's navigation environment and then to evaluate the safety of the ship's navigation environment. Obviously, evaluation of the ship navigation environment safety is a classical MAGDM problem. In this section, a numerical example is provided to evaluate the ship navigation environment safety by using EDAS method with PI2TLNs. Assume that there are five possible ship navigations P_i ($i = 1, 2, 3, 4, 5$) to be assessed by four evaluation attributes σ_j ($j = 1, 2, 3, 4$): (1) σ_1 is the hydrometeorological factor; (2) σ_2 is the channel condition factor; (3) σ_3 is the channel traffic factor; and (4) σ_4 is the port condition factor. Five possible ship navigations P_i ($i = 1, 2, 3, 4, 5$) are assessed with PI2TLNs under four attributes by three experts D^k (expert's weight $\bar{\omega} = (0.25, 0.39, 0.36)$ and attributes' weight $\omega = (0.22, 0.32, 0.26, 0.20)$).

In order to get the most desirable ship navigations, the relevant calculating steps are listed below:

TABLE 1: Rating alternatives on each criterion by D_1 .

	σ_1	σ_2
P_1	$\langle [(S_3, 0), (S_4, 0)], (0.4, 0.7) \rangle$	$\langle [(S_5, 0), (S_2, 0)], (0.6, 0.1) \rangle$
P_2	$\langle [(S_5, 0), (S_2, 0)], (0.6, 0.4) \rangle$	$\langle [(S_3, 0), (S_6, 0)], (0.6, 0.5) \rangle$
P_3	$\langle [(S_5, 0), (S_6, 0)], (0.2, 0.6) \rangle$	$\langle [(S_1, 0), (S_3, 0)], (0.3, 0.8) \rangle$
P_4	$\langle [(S_2, 0), (S_3, 0)], (0.6, 0.8) \rangle$	$\langle [(S_6, 0), (S_2, 0)], (0.2, 0.9) \rangle$
P_5	$\langle [(S_1, 0), (S_1, 0)], (0.5, 0.6) \rangle$	$\langle [(S_4, 0), (S_1, 0)], (0.5, 0.7) \rangle$
	σ_3	σ_4
P_1	$\langle [(S_2, 0), (S_2, 0)], (0.5, 0.5) \rangle$	$\langle [(S_3, 0), (S_1, 0)], (0.4, 0.5) \rangle$
P_2	$\langle [(S_4, 0), (S_5, 0)], (0.2, 0.5) \rangle$	$\langle [(S_4, 0), (S_2, 0)], (0.4, 0.7) \rangle$
P_3	$\langle [(S_5, 0), (S_3, 0)], (0.6, 0.2) \rangle$	$\langle [(S_3, 0), (S_5, 0)], (0.2, 0.4) \rangle$
P_4	$\langle [(S_1, 0), (S_6, 0)], (0.3, 0.3) \rangle$	$\langle [(S_3, 0), (S_4, 0)], (0.7, 0.5) \rangle$
P_5	$\langle [(S_3, 0), (S_4, 0)], (0.6, 0.1) \rangle$	$\langle [(S_4, 0), (S_2, 0)], (0.6, 0.4) \rangle$

TABLE 2: Rating alternatives on each criterion by D_2 .

	σ_1	σ_2
P_1	$\langle [(S_1, 0), (S_3, 0)], (0.6, 0.4) \rangle$	$\langle [(S_1, 0), (S_5, 0)], (0.5, 0.7) \rangle$
P_2	$\langle [(S_3, 0), (S_5, 0)], (0.3, 0.6) \rangle$	$\langle [(S_3, 0), (S_3, 0)], (0.4, 0.2) \rangle$
P_3	$\langle [(S_4, 0), (S_6, 0)], (0.5, 0.8) \rangle$	$\langle [(S_2, 0), (S_6, 0)], (0.6, 0.3) \rangle$
P_4	$\langle [(S_3, 0), (S_2, 0)], (0.1, 0.6) \rangle$	$\langle [(S_6, 0), (S_1, 0)], (0.2, 0.8) \rangle$
P_5	$\langle [(S_4, 0), (S_1, 0)], (0.2, 0.7) \rangle$	$\langle [(S_4, 0), (S_3, 0)], (0.3, 0.9) \rangle$
	σ_3	σ_4
P_1	$\langle [(S_3, 0), (S_1, 0)], (0.5, 0.7) \rangle$	$\langle [(S_2, 0), (S_2, 0)], (0.3, 0.7) \rangle$
P_2	$\langle [(S_4, 0), (S_3, 0)], (0.6, 0.8) \rangle$	$\langle [(S_4, 0), (S_3, 0)], (0.6, 0.2) \rangle$
P_3	$\langle [(S_1, 0), (S_5, 0)], (0.7, 0.5) \rangle$	$\langle [(S_5, 0), (S_4, 0)], (0.4, 0.5) \rangle$
P_4	$\langle [(S_6, 0), (S_3, 0)], (0.2, 0.4) \rangle$	$\langle [(S_1, 0), (S_5, 0)], (0.1, 0.7) \rangle$
P_5	$\langle [(S_2, 0), (S_4, 0)], (0.6, 0.6) \rangle$	$\langle [(S_6, 0), (S_1, 0)], (0.4, 0.9) \rangle$
P_5	$\langle [(S_3, 0), (S_4, 0)], (0.6, 0.1) \rangle$	$\langle [(S_4, 0), (S_2, 0)], (0.6, 0.4) \rangle$

TABLE 3: Rating alternatives on each criterion by D_3 .

	σ_1	σ_2
P_1	$\langle [(S_1, 0), (S_4, 0)], (0.7, 0.7) \rangle$	$\langle [(S_5, 0), (S_5, 0)], (0.7, 0.3) \rangle$
P_2	$\langle [(S_6, 0), (S_5, 0)], (0.8, 0.4) \rangle$	$\langle [(S_4, 0), (S_3, 0)], (0.3, 0.6) \rangle$
P_3	$\langle [(S_2, 0), (S_1, 0)], (0.4, 0.4) \rangle$	$\langle [(S_3, 0), (S_5, 0)], (0.6, 0.7) \rangle$
P_4	$\langle [(S_1, 0), (S_3, 0)], (0.7, 0.4) \rangle$	$\langle [(S_5, 0), (S_5, 0)], (0.4, 0.4) \rangle$
P_5	$\langle [(S_5, 0), (S_4, 0)], (0.5, 0.4) \rangle$	$\langle [(S_4, 0), (S_6, 0)], (0.6, 0.5) \rangle$
	σ_3	σ_4
P_1	$\langle [(S_1, 0), (S_2, 0)], (0.3, 0.5) \rangle$	$\langle [(S_3, 0), (S_4, 0)], (0.3, 0.3) \rangle$
P_2	$\langle [(S_4, 0), (S_4, 0)], (0.5, 0.8) \rangle$	$\langle [(S_4, 0), (S_1, 0)], (0.4, 0.5) \rangle$
P_3	$\langle [(S_3, 0), (S_5, 0)], (0.6, 0.7) \rangle$	$\langle [(S_1, 0), (S_2, 0)], (0.2, 0.6) \rangle$
P_4	$\langle [(S_5, 0), (S_5, 0)], (0.4, 0.4) \rangle$	$\langle [(S_2, 0), (S_5, 0)], (0.5, 0.7) \rangle$
P_5	$\langle [(S_6, 0), (S_2, 0)], (0.5, 0.6) \rangle$	$\langle [(S_2, 0), (S_1, 0)], (0.6, 0.6) \rangle$

TABLE 4: The group Pythagorean interval 2-tuple linguistic decision matrix R .

	σ_1	σ_2
P_1	$\langle [(S_2, -0.5), (S_4, -0.39)], (0.6072, 0.6152) \rangle$	$\langle [(S_3, 0.44), (S_4, 0.25)], (0.6104, 0.5641) \rangle$
P_2	$\langle [(S_5, -0.42), (S_4, 0.25)], (0.635, 0.5891) \rangle$	$\langle [(S_3, 0.36), (S_4, -0.25)], (0.4385, 0.4442) \rangle$
P_3	$\langle [(S_4, 0.25), (S_6, -0.36)], (0.4965, 0.7627) \rangle$	$\langle [(S_2, -0.25), (S_3, 0.45)], (0.4788, 0.4496) \rangle$
P_4	$\langle [(S_4, -0.17), (S_2, 0.25)], (0.4041, 0.3577) \rangle$	$\langle [(S_4, 0.2), (S_2, -0.03)], (0.4853, 0.6591) \rangle$
P_5	$\langle [(S_4, -0.39), (S_2, 0.08)], (0.4174, 0.6256) \rangle$	$\langle [(S_4, 0), (S_4, -0.42)], (0.4859, 0.7478) \rangle$
	σ_3	σ_4
P_1	$\langle [(S_2, 0.03), (S_2, -0.39)], (0.4426, 0.678) \rangle$	$\langle [(S_3, -0.39), (S_2, 0.47)], (0.3287, 0.5641) \rangle$
P_2	$\langle [(S_4, 0), (S_4, -0.14)], (0.5001, 0.8459) \rangle$	$\langle [(S_4, 0), (S_2, 0.03)], (0.4945, 0.4159) \rangle$
P_3	$\langle [(S_3, -0.28), (S_5, -0.5)], (0.6436, 0.6712) \rangle$	$\langle [(S_3, 0.06), (S_4, -0.47)], (0.2979, 0.6349) \rangle$
P_4	$\langle [(S_4, 0.39), (S_4, 0.47)], (0.3118, 0.503) \rangle$	$\langle [(S_2, -0.14), (S_5, -0.25)], (0.491, 0.7653) \rangle$
P_5	$\langle [(S_4, -0.31), (S_3, 0.28)], (0.5678, 0.6817) \rangle$	$\langle [(S_4, 0.06), (S_1, 0.25)], (0.537, 0.7985) \rangle$

TABLE 5: The score values of g_{ij} and AV_j .

	σ_1	σ_2	σ_3	σ_4
P_1	2.5300	4.0542	1.3400	2.0062
P_2	4.6627	3.5372	2.1008	3.2306
P_3	3.2877	2.6705	3.4792	2.2589
P_4	3.1475	2.4714	3.7399	2.1661
P_5	2.2270	2.5656	2.9889	1.7277
SAV_j	3.3803	3.1769	2.8299	2.4130

TABLE 6: The results of PDA_{ij} .

	σ_1	σ_2	σ_3	σ_4
P_1	0.0000	0.2761	0.0000	0.0000
P_2	0.3794	0.1134	0.0000	0.3389
P_3	0.0000	0.0000	0.2294	0.0000
P_4	0.0000	0.0000	0.3216	0.0000
P_5	0.0000	0.0000	0.0562	0.0000

TABLE 7: The results of NDA_{ij} .

	σ_1	σ_2	σ_3	σ_4
P_1	0.2515	0.0000	0.5265	0.1686
P_2	0.0000	0.0000	0.2576	0.0000
P_3	0.0274	0.1594	0.0000	0.0638
P_4	0.0689	0.2221	0.0000	0.1023
P_5	0.3412	0.1924	0.0000	0.2840

TABLE 8: The values of SP_i and SN_i .

	P_1	P_2	P_3	P_4	P_5
SP_i	0.0884	0.1875	0.0596	0.0836	0.0146
SN_i	0.2259	0.0670	0.0698	0.1067	0.1934

TABLE 9: The values of NSP_i and NSN_i .

	P_1	P_2	P_3	P_4	P_5
NSP_i	0.4712	1.0000	0.3181	0.4458	0.0779
NSN_i	0.0000	0.7035	0.6911	0.5278	0.1439

Step 1. Construct the evaluation matrix $T^{(k)} = (t_{ij}^k)_{5 \times 4}$ ($i = 1, 2, \dots, 5, j = 1, 2, \dots, 4$) of each decision maker as in Tables 1–3.

Step 2. Use PI2TLWA operator to integrate evaluation information from decision makers (expert's weight $\omega = (0.25, 0.39, 0.36)$). The results are presented in Table 4.

Step 3. Calculate the value of (AV_j) :

$$\begin{aligned}
 AV_1 &= \left\{ \begin{aligned} &\left[\Delta \left(\frac{1}{5} \times 1.5000 + \frac{1}{5} \times 4.5800 + \frac{1}{5} \times 4.2500 + \frac{1}{5} \times 3.8300 + \frac{1}{5} \times 3.6100 \right), \right. \\ &\left. \Delta \left(\frac{1}{5} \times 3.6100 + \frac{1}{5} \times 4.2500 + \frac{1}{5} \times 5.6400 + \frac{1}{5} \times 2.2500 + \frac{1}{5} \times 2.0800 \right) \right] \\ &\left(\sqrt{ \frac{1 - (1 - 0.6072^2)^{1/5} \times (1 - 0.6350^2)^{1/5} \times (1 - 0.4965^2)^{1/5}}{(0.6152)^{1/5} \times (0.5891)^{1/5} \times (0.7627)^{1/5} \times (0.3577)^{1/5} \times (0.6256)^{1/5}} } \right. \\ &\quad \left. \times (1 - 0.4041^2)^{1/5} \times (1 - 0.4174^2)^{1/5} \right) \end{aligned} \right\} \\
 &= \langle [(s_4, -0.4460), (s_4, -0.4340)], (0.5273, 0.5732) \rangle, \\
 AV_2 &= \left\{ \begin{aligned} &\left[\Delta \left(\frac{1}{5} \times 3.4400 + \frac{1}{5} \times 3.3600 + \frac{1}{5} \times 1.7500 + \frac{1}{5} \times 4.2000 + \frac{1}{5} \times 4.0000 \right), \right. \\ &\left. \Delta \left(\frac{1}{5} \times 4.2500 + \frac{1}{5} \times 3.7500 + \frac{1}{5} \times 3.4500 + \frac{1}{5} \times 1.9700 + \frac{1}{5} \times 3.5800 \right) \right] \\ &\left(\sqrt{ \frac{1 - (1 - 0.6104^2)^{1/5} \times (1 - 0.4385^2)^{1/5} \times (1 - 0.4788^2)^{1/5}}{(0.5641)^{1/5} \times (0.4442)^{1/5} \times (0.4496)^{1/5} \times (0.6591)^{1/5} \times (0.7478)^{1/5}} } \right. \\ &\quad \left. \times (1 - 0.4853^2)^{1/5} \times (1 - 0.4859^2)^{1/5} \right) \end{aligned} \right\} \\
 &= \langle [(s_3, -0.3500), (s_3, 0.4000)], (0.5059, 0.5609) \rangle, \\
 AV_3 &= \left\{ \begin{aligned} &\left[\Delta \left(\frac{1}{5} \times 2.0300 + \frac{1}{5} \times 4.0000 + \frac{1}{5} \times 2.7200 + \frac{1}{5} \times 4.3900 + \frac{1}{5} \times 3.6900 \right), \right. \\ &\left. \Delta \left(\frac{1}{5} \times 1.6100 + \frac{1}{5} \times 3.8600 + \frac{1}{5} \times 4.5000 + \frac{1}{5} \times 4.4700 + \frac{1}{5} \times 3.2800 \right) \right] \\ &\left(\sqrt{ \frac{1 - (1 - 0.4426^2)^{1/5} \times (1 - 0.5001^2)^{1/5} \times (1 - 0.6436^2)^{1/5}}{(0.6780)^{1/5} \times (0.8459)^{1/5} \times (0.6712)^{1/5} \times (0.5030)^{1/5} \times (0.6817)^{1/5}} } \right. \\ &\quad \left. \times (1 - 0.3118^2)^{1/5} \times (1 - 0.5678^2)^{1/5} \right) \end{aligned} \right\} \\
 &= \langle [(s_3, 0.3660), (s_4, -0.4560)], (0.5137, 0.6670) \rangle, \\
 AV_4 &= \left\{ \begin{aligned} &\left[\Delta \left(\frac{1}{5} \times 2.6100 + \frac{1}{5} \times 4.0000 + \frac{1}{5} \times 3.0600 + \frac{1}{5} \times 1.8600 + \frac{1}{5} \times 4.0600 \right), \right. \\ &\left. \Delta \left(\frac{1}{5} \times 2.4700 + \frac{1}{5} \times 2.0300 + \frac{1}{5} \times 3.5300 + \frac{1}{5} \times 4.7500 + \frac{1}{5} \times 1.2500 \right) \right] \\ &\left(\sqrt{ \frac{1 - (1 - 0.3287^2)^{1/5} \times (1 - 0.4945^2)^{1/5} \times (1 - 0.2979^2)^{1/5}}{(0.5641)^{1/5} \times (0.4159)^{1/5} \times (0.6349)^{1/5} \times (0.7653)^{1/5} \times (0.7985)^{1/5}} } \right. \\ &\quad \left. \times (1 - 0.4910^2)^{1/5} \times (1 - 0.5370^2)^{1/5} \right) \end{aligned} \right\} \\
 &= \langle [(s_3, 0.1180), (s_3, -0.1940)], (0.4451, 0.6192) \rangle.
 \end{aligned} \tag{20}$$

So, the values of AV_j are determined as follows:

$$AV_{1 \times 4} = \left\{ \begin{array}{l} \langle [(s_4, -0.4460), (s_4, -0.4340)], (0.5273, 0.5732) \rangle, \\ \langle [(s_3, -0.3500), (s_3, 0.4000)], (0.5059, 0.5609) \rangle, \\ \langle [(s_3, 0.3660), (s_4, -0.4560)], (0.5137, 0.6670) \rangle, \\ \langle [(s_3, 0.1180), (s_3, -0.1940)], (0.4451, 0.6192) \rangle \end{array} \right\}. \quad (21)$$

Step 4. Based on the results of average solution (AV_j), equations (14) and (15) are used to calculate PDA_{ij} and NDA_{ij} (see Tables 5–7).

Step 5. Compute the values of SP_i and SN_i by equation (17) (weighting vector $\omega = (0.22, 0.32, 0.26, 0.20)$), and the results are depicted in Table 8.

Step 6. Normalize the results of Step 6 by equation (18), and the results are presented in Table 9.

Step 7. Compute AS_i ($i = 1, 2, 3, 4, 5$):

$$\begin{aligned} AS_1 &= 0.2356, \\ AS_2 &= 0.8518, \\ AS_3 &= 0.5046, \\ AS_4 &= 0.4868, \\ AS_5 &= 0.1109. \end{aligned} \quad (22)$$

Step 8. According to the calculation results, the greater the value of AS_i , the better the alternative, so the order of all alternatives is $P_2 > P_3 > P_4 > P_1 > P_5$; P_2 is the best alternative.

5. Conclusion

In MAGDM methods, uncertainty and hesitation are usually unavoidable. PI2TLNs are more likely to reflect uncertain or ambiguous information. At the same time, the EDAS method has the characteristics of small computation and few steps. Therefore, this paper proposes the PI2TLN-EDAS method to solve the MAGDM problem of PI2TLNs. Then, taking ship navigation environment safety evaluation as an example, the effectiveness and practicability of the method are verified through comparative analysis. Further research will carry out other applications of this method in other uncertain MAGDM problems [65–68] and other fields [69–75].

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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