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Ship-bridge Collision Risk Assessment Based On Intuitionistic Fuzzy Set

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Abstract

To effectively eliminate the fuzziness of indicators in the process of ship-bridge collision risk assessment, an intuitionstic fuzzy set theory is introduced to establish a ship-bridge collision risk assessment model. The model selects 10 risk evaluation indicators to form an index set, and the risk division criteria constitutes an evaluation set. The intuitionistic fuzzy numbers are converted into an intuitionistic fuzzy decision matrix according to the index set and the evaluation set, and then the objective weights of each index factor are calculated using the intuitionistic fuzzy entropy formula. The analytical method computes the subjective weights, and obtains the combined weights from the idea of intuitionistic fuzzy set theory, so as to calculate the comprehensive value of the evaluation sample. The verification of an example shows that the evaluation results of the intuitionistic fuzzy set theory and the fuzzy matter-element theory are generally close, and the theory is feasible and effective, and provides a new method for evaluating ship-bridge collision risk.

Keywords

IFS; Ship-bridge Collision; Intuitionistic Fuzzy Entropy; Risk Assessment.

1. Introduction

The number of bridges in navigable waters, such as rivers and seas, is increasing with years [1]. The intensive routes, the rising and rapid trend of the number of ships have caused the increase in the number of bridges and bridges and the risk of collision, which has attracted the attention of maritime related departments.

The research on ship-bridge collision risk assessment has been carried out extensively at present. Wang Zengzhong [2] evaluated the risk of a ship hitting a bridge based on the life of the bridge. Huang Changhai [3] constructed a navigation safety risk system for bridge area waters, a risk cause system that aggravates and mitigates the consequences of accidents, and established a risk assessment model for bridge area waters navigation safety. Ou Lijian [4] analyzed the collision risk of a ship based on the AASHTTO probability calculation model. Chen Weijiong [5] used fuzzy Bow-tie model to establish a risk assessment model for ship-to-bridge collision of a sea-crossing bridge, and realized the transition from qualitative to quantitative assessment of ship-to-bridge collision risk. WU [6] determined the ship-bridge collision risk based on fuzzy logic theory and used it to improve ship maneuvering in the bridge waterway area. Zhong Jun [7] used a combination of weights and fuzzy matter-element model to quantitatively evaluate the risk of ship-bridge collision. According to the research on the above literature, it is known that the risk of ship-bridge collision is affected by many factors. Most scholars need to select specific indicators in order to fully reveal the risk situation of ship-bridge collision. However, ship-bridge collision risk indicators are often ambiguous. How to

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effectively eliminate the ambiguity of risk assessment factors and transform them from qualitative to quantitative research is the hot and difficult point of current research.

In the field of intuitionistic fuzzy set theory, in 1983, the intuitionistic fuzzy set developed by Bulgarian scholar Atanassov [8] is a pair of fuzzy sets, that is, membership functions and non-membership functions, which represent the positive and negative of a given information, and can be more comprehensively expressed Vagueness of information [9]. After decades of development, the intuitionistic fuzzy set theory has been widely used in many disciplines. Muhammet [10] used the intuitionistic fuzzy set theory to carry out a risk evaluation of the service quality of buses, and extracted the most important indicators that affect the service quality based on the evaluation results, providing reference information for the management of buses. Yin Xin [11] applied the intuitionistic fuzzy set theory to the evaluation of the expansion and contraction grades of expansive soil, and effectively dealt with the ambiguity of the indicators during the evaluation process. In order to eliminate the ambiguity of the indicators in the ship-bridge collision risk assessment, and to ensure that objective and accurate evaluation results are obtained. In this paper, an intuitionistic fuzzy set theory is used to establish a ship-bridge collision risk assessment model, and an example is used to verify the feasibility and effectiveness of the model.

2. Intuitionistic fuzzy set and related theory

2.1 Intuitionistic fuzzy set

Definition1: Let X for a set, if $\mu_A : X \to [0,1]$, $\nu_A : X \to [0,1]$, satisfies:

$$\mu_A + \nu_A \le 1, \forall x \in X \tag{1}$$

Then $A = (X, \mu_A, \nu_A)$ is called an intuitionistic fuzzy subset on X, Where $\mu_A(x)$ is the degree of membership of element x to A, and $\nu_A(x)$ is the degree of non-membership of element x to A.

Definition2: If $\forall x \in X$, $\pi_A(x) = 1 - \mu_A(x) - \nu_A(x)$, $0 \le \pi_A(x) \le 1$, then call $\pi_A(x)$ as the hesitation degree of A.

According to the definition, the element composed by membership $\mu_A(x)$, non-membership $\nu_A(x)$ and hesitancy degree $\pi_A(x)$ is called intuitionistic fuzzy number ($\alpha = (\mu, \nu)$)[8].

For any three intuitive fuzzy numbers, $\alpha = (\mu_\alpha, \nu_\alpha)$, $\alpha_1 = (\mu_{\alpha_1}, \nu_{\alpha_1})$, $\alpha_2 = (\mu_{\alpha_2}, \nu_{\alpha_2})$, Its calculation formula [12] is as follows:

$$\lambda\alpha = \left(1 - (1 - \mu_\alpha)^\lambda, {\nu_\alpha}^\lambda\right) \tag{2}$$

$$\alpha^\lambda = \left({\mu_\alpha}^\lambda, 1 - (1 - \nu_\alpha)^\lambda\right) \tag{3}$$

$$\alpha_1 \oplus \alpha_2 = \left(\mu_{\alpha_1} + \mu_{\alpha_2} - \mu_{\alpha_1} * \mu_{\alpha_2}, \nu_{\alpha_1} * \nu_{\alpha_2}\right) \tag{4}$$

$$\alpha_1 \otimes \alpha_2 = \left(\mu_{\alpha_1} * \mu_{\alpha_2}, \nu_{\alpha_1} + \nu_{\alpha_2} - \nu_{\alpha_1} * \nu_{\alpha_2}\right) \tag{5}$$

2.2 Intuitionistic fuzzy entropy

Definition2: Let $X = \{x_1, x_2, \cdots, x_n\}$, $A = \{x_i, \mu_A(x_i), \nu_A(x_i) | x_i \in X\}$ is the intuitionistic fuzzy set on X, based on the difference between membership degree and non-membership degree in the intuitionistic fuzzy number $|\mu_A(x_i) - \nu_A(x_i)|$ and the hesitant membership degree $\pi_A(x_i)$, the calculation formula of the intuitionistic fuzzy entropy is as follows:

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$$E(A)=\frac{1}{n}\sum_{i=1}^{n}\frac{1-\left|\mu_A(x_i)-\nu_A(x_i)\right|+\pi_A(x_i)}{1+\left|\mu_A(x_i)-\nu_A(x_i)\right|+\pi_A(x_i)} \tag{5}$$

3. Method

3.1 Indicator set and evaluation set

Assuming that there are M factors (risk indicators) for ship-bridge collisions and N for risk assessment levels, the indicator set X and evaluation set S for ship-bridge collisions are:

$$X=\{x_1,x_2,\cdots,x_m\} \tag{6}$$

$$S=\{x_1,x_2,\cdots,x_n\} \tag{7}$$

3.2 IFS decision matrix

Construct an intuitionistic fuzzy decision matrix F, convert the m-th index value X in the ship-bridge collision risk data sample into the membership degree μ_{mn} and non-membership degree ν_{mn} of the corresponding safety standard interval $\left[\overline{S}_n,\underline{S}_n\right]$, and then write the intuitionistic fuzzy set:

$$\mathrm{A}_{mn}=\langle\mu_{mn},\nu_{mn}\rangle \tag{8}$$

The calculation formula[14]for converting the index value x_m into the corresponding interval membership degree μ_{mn}, non-membership degree ν_{mn}, and hesitation degree π_{mn} is as follows:

$$\mu_{mn}=\exp\left[-\frac{\left(x_m-c_{\mu n}\right)^2}{2\sigma_{\mu n}^2}\right] \tag{9}$$

$$\nu_{mn}=1-\exp\left[-\frac{\left(x_m-c_{\nu n}\right)^2}{2\sigma_{\nu n}^2}\right] \tag{10}$$

$$c_{\mu n}=c_{\nu n}=\frac{\overline{S}_n+\underline{S}_n}{2} \tag{11}$$

$$\sigma_{\mu n}^2=-\frac{\left(\overline{S}_n-c_{\mu n}\right)^2}{2ln\frac{1-\alpha}{2}} \tag{12}$$

$$\sigma_{\nu n}^2=-\frac{\left(\underline{S}_n-c_{\nu n}\right)^2}{2ln\left(1+\frac{1-\alpha}{2}\right)} \tag{13}$$

$$\pi_{mn}=1-\mu_{mn}-\nu_{mn} \tag{14}$$

In the above formula, $c_{\mu n}$, $c_{\nu n}$, $\sigma_{\nu n}^2$ and $\sigma_{\mu n}^2$ is the calculation parameter of membership and non-membership; α is the intuitionistic fuzzy hesitation degree, take 0.2 [15].

Then the sample intuitionistic fuzzy set decision matrix obtained according to the formula is:

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$$F = \begin{matrix} & s_1 & s_2 & \cdots & s_n \\ x_1 \\ x_2 \\ \vdots \\ x_m \end{matrix}\begin{bmatrix} \mu_{11},\nu_{11} & \mu_{12},\nu_{12} & \cdots & \mu_{1n},\nu_{1n} \\ \mu_{21},\nu_{21} & \mu_{22},\nu_{22} & \cdots & \mu_{2n},\nu_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \mu_{m1},\nu_{m1} & \mu_{m2},\nu_{m2} & \cdots & \mu_{mn},\nu_{mn} \end{bmatrix}$$

3.3 Determination of indicator weights

Since the risk evaluation index has different degrees of influence on the risk evaluation results of the ship and bridge, reasonably determining the weight of the evaluation index is a prerequisite for effective evaluation. Based on the AHP and the intuitionistic fuzzy entropy theory, the weights of the subject and the passenger of the ship-bridge collision risk index are weighted. Based on the intuitionistic fuzzy set theory, the weights are determined (the index weight is expressed based on the intuitionistic fuzzy set), which fully reflects the weight The ambiguity of the method improves the rationality, accuracy and validity of the results of the ship-bridge collision risk assessment.

The subjective weight is determined by the AHP, and the specific algorithms are referenced in the literature. Let the subjective weight of the ship-bridge collision risk evaluation index be:

$$\alpha = [\alpha_1, \alpha_2, \cdots, \alpha_m]$$

Objective weights are determined using intuitionistic fuzzy entropy theory,let $\mathrm{Y} = \{y_1, y_2, \cdots, y_k\}$ is a sample of collision risk data for group k of bridges, the formula (1) can be used to calculate the intuitionistic fuzzy entropy value $E_i\,(i = 1, 2, \cdots, m)$ of the risk data samples for each group of straight bridges, the intuitionistic fuzzy entropy matrix obtained in this paper is as follows:

$$\bar{E} = \begin{matrix} & x_1 & x_2 & \cdots & x_m \\ y_1 \\ y_2 \\ \vdots \\ y_k \end{matrix}\begin{bmatrix} E_{11} & E_{12} & \cdots & E_{1m} \\ E_{21} & E_{22} & \cdots & E_{2m} \\ \vdots & \vdots & \cdots & \vdots \\ E_{k1} & E_{k2} & \cdots & E_{km} \end{bmatrix}$$

Then calculating the objective weight of the indicator by the following formula:

$$\beta_i = 1 - \frac{1}{n}\sum_{j=1}^{n} E_{ij} \Big/ \sum_{i=1}^{m}\left(1 - \frac{1}{m}\sum_{i=1}^{n} E_{ij}\right)\left(i = 1, 2\cdots, m;\ j = 1, 2, \cdots, k\right) \tag{15}$$

Expressing the combined weights in an intuitionistic fuzzy set [15] :

$$w_m = \langle \rho_m, \tau_m \rangle \tag{16}$$

$$\rho_m = \min(\alpha_m, \beta_m) \tag{17}$$

$$\tau_m = 1 - max(\alpha_m, \beta_m) \tag{18}$$

Where: w_m is the combined weight expressed in an intuitionistic fuzzy manner; ρ_m and τ_m are the degree of importance and non-importance of the index $x_m \in X$,and $0 \le \rho_m, \tau_m \le 1$.

3.4 Ship-bridge collision risk assessment model

Combined with the weights obtained in Section 2.3, the comprehensive value of each index of the evaluation sample for the ship-bridge collision risk evaluation is calculated, and then the ship-bridge collision risk evaluation grade score is obtained. According to the intuitionistic fuzzy set size comparison method, the safety level corresponding to the largest intuitionistic fuzzy set is taken as the safety level of the ship-bridge collision risk data sample, and the ship-bridge collision risk evaluation model is as follows:

$$\overline{F_{mn}} = wF_{mn} = \rho_m \mu_{mn}, \tau_m + \nu_{mn} - \tau_m \nu_{mn} \tag{19}$$

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$$V_n = \sum_{m=1}^{M} \overline{F_{mn}} \tag{20}$$

$$M(V) = \mu_V(x) - \nu_V(x) + \frac{\pi_V(x)}{2}, M(V) \in [-1,1] \tag{21}$$

Where: V_n is the comprehensive value of sample pair safety level n; $\overline{F_{mn}}$ is the $\nu_V(x)$ weighted intuitionistic fuzzy matrix; $M(V)$ is the score of V, V is an intuitionistic fuzzy set on the non-empty set X determined by $\mu_V(x)$ and $\nu_V(x)$; $\mu_V(x), \nu_V(x)$ and $\pi_V(x)$ is the degree of membership, non-membership and hesitation of element x belonging to V.

4. Example application

4.1 Risk assessment indicators and standards for ship-bridge collisions

There are relatively few ship-bridge collisions caused by single factors.Usually, this is due to the coupling of multiple factors that lead to ship-bridge collisions. In this paper, according to previous literature [7], the ship-bridge collision indicators were determined as standard days C_1, visibility C_2, maximum water velocity in the bridge area C_3, traffic density C_4, normal angle between the channel and the bridge axis normal C_5, bridge clearance width C_6, bridge clearance height C_7, number of piers in the water C_8 , clearance height above the waterline of the largest ship passing the bridge C_9, transverse wind area of the ship C_{10}, and the safety level is divided into five levels: I, II, III, IV, and V.. Each level corresponds to 'Lower danger', 'Low danger', 'Medium danger', 'High danger', 'Higher danger'. According to the regulations of relevant departments and domestic and foreign research, the risk grading standards for the risk assessment indicators of ship-bridge collision are formed, as shown in Table 1.

Table 1: Evaluation criteria for indicator level

Evaluation index	Lower danger I	Low danger II	Medium danger III	High danger IV	Higher danger V
Standard days/d	0~30	30~60	60~100	100~150	≥ 150
Visibility/d	0~15	15~30	30~45	45~60	≥ 60
Maximum water velocity in the bridge area /(m•s^2)	0~0.8	0.8~1.6	1.6~2.6	2.6~3.6	≥ 3.6
Traffic density /(ship•d^{-1})	0~300	300~600	600~1000	1000~1500	≥ 1500
Normal angle between the channel and the bridge axis normal /(.)	0~5	5~15	15~30	30~50	50~90
Bridge clearance width /m	≥ 800	600~800	400~600	200~400	0~200
Bridge clearance height /m	≥ 50	25~50	15~25	10~15	0~10
Number of piers	0~2	2~5	5~9	9~13	≥ 13
Clearance height above the waterline of the largest ship passing the bridge /m	0~15	15~25	25~30	30~45	≥ 45
Transverse wind area of the ship /m^2	0~500	500~1000	1000~1500	1500~2000	≥ 2000

In this paper, six bridges A, B, C, D, E, and F in a river basin in [7] are selected as data samples. The evaluation index values of each bridge are shown in Table 2.

Table 2: Ship-bridge collision risk index value

Bridge number	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}

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A	28	16.5	1.79	180	13	660	18	12	21	910
B	32	16.2	1.87	145	8	778	18	3	24.63	930
C	33	33.1	2.01	428	6	512	18	8	24.63	993
D	35	7.6	2.04	458	12	735	24	6	26.6	1000
E	36	8	2.12	563	8	781.4	24	3	27.55	1116
F	35	16.2	2.21	1742	9	624	24	12	28.85	1240

4.2 Application of IFS evaluation model

Taking the evaluation index value of Bridge A as an example, the intuitive fuzzy decision matrix F of Bridge A evaluation samples can be obtained according to formula (9-14).

$$F=\begin{bmatrix} \langle 0.5025,0.2233\rangle & \langle 0.3082,0.3509\rangle & \langle 0.0020,0.8972\rangle & \langle 0.0000,0.9937\rangle & \langle 0.0154,0.7842\rangle \\ \langle 0.2673,0.3840\rangle & \langle 0.5563,0.1937\rangle & \langle 0.0008,0.9285\rangle & \langle 0.0000,0.9996\rangle & \langle 0.2201,0.4264\rangle \\ \langle 0.0000,0.9828\rangle & \langle 0.1362,0.5191\rangle & \langle 0.7031,0.1213\rangle & \langle 0.0019,0.9007\rangle & \langle 0.2553,0.3943\rangle \\ \langle 0.9640,0.0134\rangle & \langle 0.0514,0.6638\rangle & \langle 0.0001,0.9606\rangle & \langle 0.0000,0.9979\rangle & \langle 0.0000,0.9884\rangle \\ \langle 0.0000,0.9974\rangle & \langle 0.7190,0.1141\rangle & \langle 0.2299,0.4172\rangle & \langle 0.0013,0.9140\rangle & \langle 0.0006,0.9350\rangle \\ \langle 0.0051,0.8560\rangle & \langle 0.8636,0.0524\rangle & \langle 0.0958,0.5774\rangle & \langle 0.0000,0.9872\rangle & \langle 0.0000,1.0000\rangle \\ \langle 0.0085,0.8261\rangle & \langle 0.1075,0.5591\rangle & \langle 0.8636,0.0524\rangle & \langle 0.0119,0.8038\rangle & \langle 0.0020,0.8972\rangle \\ \langle 0.0000,1.0000\rangle & \langle 0.0000,1.0000\rangle & \langle 0.0033,0.8779\rangle & \langle 0.7953,0.0807\rangle & \langle 0.3184,0.3431\rangle \\ \langle 0.0514,0.6638\rangle & \langle 0.9640,0.0134\rangle & \langle 0.0020,0.8972\rangle & \langle 0.0119,0.8038\rangle & \langle 0.0402,0.6927\rangle \\ \langle 0.0017,0.9042\rangle & \langle 0.6871,0.1287\rangle & \langle 0.1836,0.4633\rangle & \langle 0.0000,0.9776\rangle & \langle 0.0000,0.9999\rangle \end{bmatrix}$$

Determine the combination weight, and calculate the subjective weight of the evaluation index by the AHP:

$$\alpha=[0.1048,0.0989,0.0915,0.0878,0.0962,0.0955,0.1339,0.1064,0.1013,0.0837]$$

Using the intuitionistic fuzzy entropy theory, the intuitionistic fuzzy entropy of each bridge is calculated according to formula (5), and the intuitionistic fuzzy matrix is formed as:

$$E=\begin{matrix} \\ A \\ B \\ C \\ D \\ E \\ F \end{matrix}\begin{bmatrix} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & C_7 & C_8 & C_9 & C_{10} \\ 0.4697 & 0.5515 & 0.4827 & 0.1338 & 0.3294 & 0.2279 & 0.3330 & 0.3065 & 0.3071 & 0.3158 \\ 0.4873 & 0.5635 & 0.4183 & 0.0902 & 0.2177 & 0.3617 & 0.3330 & 0.2594 & 0.6648 & 0.3481 \\ 0.4701 & 0.4904 & 0.3470 & 0.2225 & 0.3954 & 0.1716 & 0.3330 & 0.3690 & 0.6648 & 0.4171 \\ 0.4255 & 0.2588 & 0.3399 & 0.2180 & 0.2536 & 0.2105 & 0.4318 & 0.3336 & 0.5304 & 0.4179 \\ 0.4018 & 0.2668 & 0.3355 & 0.4033 & 0.2177 & 0.3730 & 0.4318 & 0.2594 & 0.4820 & 0.2750 \\ 0.4255 & 0.5635 & 0.3558 & 0.1579 & 0.1755 & 0.3637 & 0.4318 & 0.3065 & 0.5430 & 0.1665 \end{bmatrix}$$

According to formula (8), the objective indicator weights are calculated as:

$$\beta=[0.0932,0.0930,0.0983,0.1117,0.1071,0.1055,0.0981,0.1039,0.0867,0.1026]$$

The intuitionistic fuzzy combination weights obtained according to formula (16-18) are shown in Table 3.

Table 3: Indicator weight value

index	Combined weight w_m
C_1	$<0.0932,0.8952>$
C_2	$<0.0930,0.9011>$
C_3	$<0.0915,0.9017>$
C_4	$<0.0878,0.8883>$
C_5	$<0.0962,0.8929>$
C_6	$<0.0955,0.8945>$
C_7	$<0.0981,0.8661>$
C_8	$<0.1039,0.8936>$
C_9	$<0.0867,0.8987>$
C_{10}	$<0.0837,0.8974>$

Calculate the weighted intuitionistic fuzzy decision matrix according to formula (19) as:

$$\overline{F_{mn}}=\begin{bmatrix}\langle 0.0468,0.9186\rangle & \langle 0.0287,0.9320\rangle & \langle 0.0002,0.9892\rangle & \langle 0.0000,0.9993\rangle & \langle 0.0014,0.9774\rangle \\ \langle 0.0249,0.9391\rangle & \langle 0.0517,0.9203\rangle & \langle 0.0001,0.9929\rangle & \langle 0.0000,1.0000\rangle & \langle 0.0205,0.9433\rangle \\ \langle 0.0000,0.9983\rangle & \langle 0.0125,0.9527\rangle & \langle 0.0643,0.9136\rangle & \langle 0.0002,0.9902\rangle & \langle 0.0234,0.9405\rangle \\ \langle 0.0846,0.8898\rangle & \langle 0.0045,0.9625\rangle & \langle 0.0000,0.9956\rangle & \langle 0.0000,0.9998\rangle & \langle 0.0000,0.9987\rangle \\ \langle 0.0000,0.9997\rangle & \langle 0.0692,0.9051\rangle & \langle 0.0221,0.9376\rangle & \langle 0.0001,0.9908\rangle & \langle 0.0001,0.9930\rangle \\ \langle 0.0005,0.9848\rangle & \langle 0.0825,0.9000\rangle & \langle 0.0091,0.9554\rangle & \langle 0.0000,0.9987\rangle & \langle 0.0000,1.0000\rangle \\ \langle 0.0008,0.9767\rangle & \langle 0.0105,0.9410\rangle & \langle 0.0847,0.8731\rangle & \langle 0.0012,0.9737\rangle & \langle 0.0002,0.9862\rangle \\ \langle 0.0000,1.0000\rangle & \langle 0.0000,1.0000\rangle & \langle 0.0003,0.9870\rangle & \langle 0.0826,0.9022\rangle & \langle 0.0331,0.9301\rangle \\ \langle 0.0045,0.9659\rangle & \langle 0.0836,0.9001\rangle & \langle 0.0002,0.9896\rangle & \langle 0.0010,0.9801\rangle & \langle 0.0035,0.9689\rangle \\ \langle 0.0001,0.9902\rangle & \langle 0.0575,0.9106\rangle & \langle 0.0154,0.9449\rangle & \langle 0.0000,0.9977\rangle & \langle 0.0000,1.0000\rangle\end{bmatrix}$$

Calculate the sample average value according to formula (13): $V_1=\langle 0.1611,0.7048\rangle$, $V_2=\langle 0.3868,0.4941\rangle$, $V_3=\langle 0.1955,0.6449\rangle$, $V_4=\langle 0.0849,0.8409\rangle$, $V_5=\langle 0.0815,0.7642\rangle$.

Obtain the intuitionistic fuzzy score value of the bridge A data sample according to formulas (14) and (20-21):

$$M=\begin{pmatrix}M(V_1)\\M(V_2)\\M(V_3)\\M(V_4)\\M(V_5)\end{pmatrix}=\begin{pmatrix}-0.5437\\-0.1072\\-0.4495\\-0.7560\\-0.6828\end{pmatrix}$$

The magnitude of the intuitionistic fuzzy scores of the evaluation samples of Bridge A can be used to obtain the ship-bridge collision risk level: $M(V_2)>M(V_3)>M(V_1)>M(V_5)>M(V_4)$.According to the size of the ranking, the risk score II score is the largest, and the risk rank IV score is the smallest. According to the intuitionistic fuzzy theory, the risk level corresponding to the maximum value of the sample intuitionistic fuzzy score is the sample risk level. Therefore, the risk level corresponding to Bridge A is level II (low risk level).

Similarly, calculate the intuitionistic fuzzy scores and risk levels of all bridges, and compare the evaluation results of the intuitionistic fuzzy set theory with the fuzzy matter-element model, as shown in Table 5.

Table 5: Model evaluation results and comparison

Bridge number	Lower danger I	Low danger II	Medium danger III	High danger IV	Higher danger IV	Evaluation results of this paper	Evaluation results of fuzzy matter-element model[7]
A	−0.5437	−0.1072	−0.4495	−0.7560	−0.6828	II	II
B	−0.4845	−0.0402	−0.4264	−0.9104	−0.7481	II	II
C	−0.7652	−0.2432	−0.0112	−0.8112	−0.7057	III	III
D	−0.6301	−0.0771	−0.1830	−0.8866	−0.7377	II	II
E	−0.5795	−0.0854	−0.2388	−0.8744	−0.7482	II	II
F	−0.7842	−0.2559	−0.2865	−0.6482	−0.5289	II	II

According to Table 5, the evaluation results based on the intuitionistic fuzzy set theory are basically consistent with the evaluation results using the fuzzy matter-element model. Danger level, the bridge "C" is in the Grade III medium risk level, of which the bridge "F" is biased towards the Grade III medium risk level. In summary, it is effective and feasible to evaluate ship-bridge collision based on intuitionistic fuzzy set theory.

5. Conclusion

1) In the intuitionistic fuzzy environment, this paper uses the intuitionistic fuzzy entropy formula to calculate the objective weights of each rating index, and combines subjective weights into

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intuitionistic fuzzy sets to make the index weights fuzzy and fully reflect the impact of subjective and objective weights on the evaluation results.

2) Compared with other methods, a ship-bridge collision risk evaluation model based on intuitionistic fuzzy sets has double fuzziness of index weights and fuzziness of indexes belonging to various levels, which can improve the accuracy of ship-bridge collision risk assessment.

3) The case verification shows that the results of the ship-bridge collision risk assessment of intuitionistic fuzzy set theory and fuzzy matter-element theory are generally close. This method is reasonable and feasible for evaluating ship-bridge collision risk, and provides a new method for evaluating ship-bridge collision risk.

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