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A Study on the Grey Evaluation Method of Ship Safety Risk

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Keyword: Ship, safety risk, analytic hierarchy process, evaluation.

Abstract: The ship safety risk evaluation index system is established according to the man-machine-environment theory, the specific ship safety risk assessment model is designed by Analytic Hierarchy Process and grey cluster method. The feasibility and feasibility of this method are verified by example.

1. Introduction

With the continuous development of China shipping industry, Ship transportation plays an increasingly important role in the national economy. While the safety of the ship is the prerequisite for transportation. At present, the ship safety has been studied in many aspects by national professionals, AHP method, relative comparison method, fuzzy evaluation method and matrix method have been used in these study. Operation of ship is a complex system, various factors are highly at random and hard to be measured, therefore, the above all kinds of safety assessment method are limits. The safety evaluation index of ship was screened scientifically according to human - ship - environment three elements. And ship safety evaluation model was established. [1]

2. Ship Safety Risk Assessment Model

2.1 Evaluation Index System.

Five primary indexes U_i (The serial Numbers from left to right are 1, 2, 3, 4, 5 respectively) and 21 secondary indexes U_{ij}(from left to right) of safety evaluation system are constructed as Ship safety risk evaluation index system according to these three factors and the actual situation of the ship. As shown in figure 1.

Fig1 Ship safety risk evaluation index system.

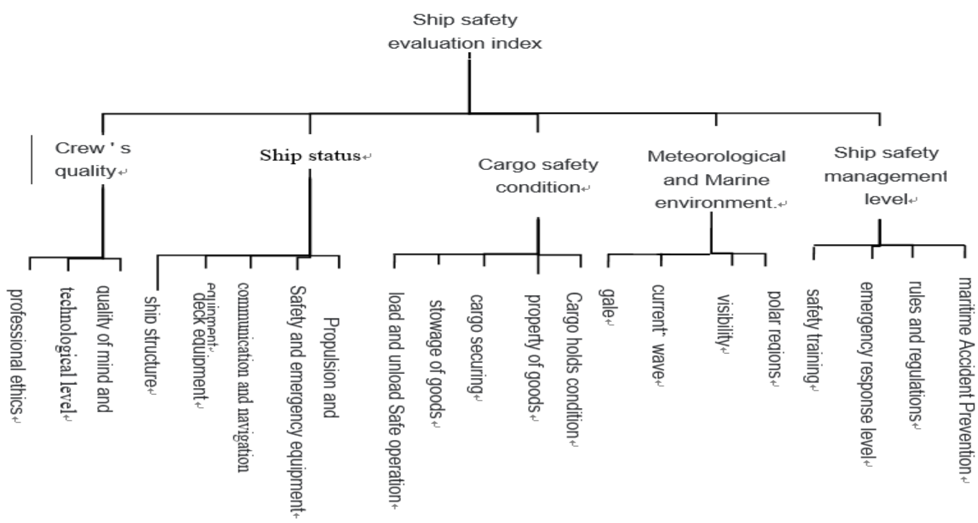

Fig 1. Ship safety risk evaluation index system.

2.2 Evaluation Index Weight.

Index weights could be confirmed by many kinds of way, analytic hierarchy process and expert scoring method were used in this article. Acquire average value after get the weight set of the experts, first grade assessment indicator were graded by some m professor value denote as d_{im} $(i=1,2,\Lambda,5)$, satisfy $\sum_{i=1}^{5} d_{im}=1, d_{im}\geq 0$. For every U_i, the weight of primary evaluation index is obtained by the evaluation of the index by the experts, denote as: X=$[a_1 \quad a_2 \quad a_3 \quad a_4 \quad a_5]$, therein to

$$a_i=\frac{1}{m}\sum d_{im} \quad (i=1,2,\Lambda,5) \tag{1}$$

Secondary evaluation index weight is obtained as well, grade by experts and then averaging. The secondary indicators of a certain level of evaluation was graded by the experts, calculate average value according to Secondary evaluation index scores, and obtain the weight of the secondary evaluation index. Calculate Weight of other secondary evaluation indicators as well. The second level indicators (5) under the third level index (set as u_3) are graded by some m professor, the results mark as d_{3jm}, there are

$$D=\begin{bmatrix} d_{311} & d_{312} & \Lambda & d_{11m} \\ d_{321} & d_{322} & \Lambda & d_{32m} \\ M & M & \Lambda & M \\ d_{3j1} & d_{3j2} & \Lambda & d_{3jm} \end{bmatrix} \tag{2}$$

In the formula, each column represents the score of each secondary index under the third level indicator, set as $\sum_{j=1}^{5} d_{3jm}=1, d_{3jm}\geq 0$, each row represents the score of m experts on the same secondary index. The weight of the secondary index can be obtained by averaging each line, denote as $\beta_{3j}=\frac{1}{m}\sum_{l=1}^{m} d_{3jl}$, l is number of experts. The weight of a secondary indicator under four other primary indicators can be obtained in a similar way, denote as

$X_i=\lfloor \beta_{i1} \quad \beta_{i2} \quad \Lambda \quad \beta_{ij} \rfloor$, In the formula $\beta_{ij}\geq 0, \sum_{j=1}^{n_i}\beta_{ij}=1$ $(i=1,2,\Lambda,5)$ n_i is the number of secondary indicators in each first grade indexes, n_i equal to3, 5, 5, 4, 4 respectively from figure 1 know

2.3 Comprehensive Evaluation of Ship Safety Risk.

Let $V=\{v_2, v_2, \Lambda, v_m\}$ set of decisions made for m, called the decision set, like five scale is used in this article, the safety risk level of the secondary evaluation index is divided into 5 levels. Give five levels of evaluation collection.

$V=\{v_1, v_2, \Lambda, v_5\}=\{$low risk, standard risk, high risk, higher risk, highest risk$\}$, each assignment 1, 2, 3, 4, 5. The greater the value, the greater the risk. When an expert thinks the risk level of an indicator is between two adjacent levels, assignable 1.5, 2.5, 3.5, 4.5.Now ask the m experts for comments, grade 21 secondary indicators. The expert serial number is $k=1,2,\Lambda,m$, The Kath expert marks the second-level evaluation index u_{ij}, denote as d_{ijk} The evaluation sample matrix of ship safety risk is obtained according to the grade of 21 secondary indicators by m experts (figure 3), Each column is an expert grading 21 secondary indicators, each row is rated by m experts on the level of the same secondary index. [2]

$$D=\begin{bmatrix} d_{111} & d_{112} & \Lambda & d_{11m} \\ d_{121} & d_{122} & \Lambda & d_{12m} \\ M & M & \Lambda & M \\ d_{211} & d_{212} & \Lambda & d_{21m} \\ M & M & \Lambda & M \\ d_{541} & d_{542} & \Lambda & d_{54m} \end{bmatrix} \tag{3}$$

2.3.1 The Subordinate Function of the Relative Risk Level of the Secondary Index.

Ship safety risk rating is rated 1 to 5 in this article, standard risk, high risk, higher risk, maximum Risk, mark as serial number $V = 1,2,\cdots,5$, the relative membership function is set to $f_v(d_{ijk})$, there are

$$f_v(d_{ijk}) = \begin{cases} \left.\begin{array}{ll} 1 & d_{ijk} \le 1 \\ 2-d_{ijk} & 1 \le d_{ijk} \le 2 \\ 0 & d_{ijk} > 2 \end{array}\right\} V = 1 \\ \left.\begin{array}{ll} d_{ijk} - (v-1) & (v-1) \le d_{ijk} \le v \\ (v+1) - d_{ijk} & v \le d_{ijk} \le v+1 \\ 0 & d_{ijk} > v+1 \text{ or } d_{ijk} < v-1 \end{array}\right\} 2 \le V \le 4 \\ \left.\begin{array}{ll} d_{ijk} - (v-1) & v-1 \le d_{ijk} \le v \\ 1 & d_{ijk} \ge v \\ 0 & d_{ijk} < v-1 \end{array}\right\} V = 5 \end{cases} \tag{4}$$

The relative grades of each secondary index in figure 3 are calculated in formula4, as a result:

$$D' = \begin{bmatrix} d_{1111} & d_{1112} & \cdots & d_{1115} \\ \vdots & \vdots & \cdots & \vdots \\ d_{5jm1} & d_{5jm2} & \cdots & d_{5jm5} \end{bmatrix} \tag{5}$$

The line indicates that all experts have a rating of the grade of the secondary indicators relative to the membership of the different risk classes, the column represents the number of grades that all experts assign to each secondary index relative to a certain level of risk. [3]

2.3.2 The Relative Membership Degree of the Secondary Evaluation Index Relative to the Risk Level.

The relative membership degree of each secondary evaluation index can be calculated by using equation (5), For example, use the first m row of the equation (5) to calculate the relative membership degree of the first secondary index under the first level index. u_{11} belongs to the sum of the membership of the V risk level $h_{11v} = \sum_{m=1}^{m} d_{11m1}$, p_{11v} is the ratio of h_{11v} to $h_{11} = \sum_{v=1}^{5} h_{11v} = \sum_{v=1}^{5}\sum_{m=1}^{m} d_{11m1}$, expressing the intensity of the level of risk belonging to V, The greater the ratio, the higher the degree of recognition u_{11} belongs to the V risk level. So it can be expressed relative membership degree that u_{11} belong to V, denote as $p_{11v} = [p_{111} \quad p_{112} \quad \cdots \quad p_{115}]$ In the same way, the relative membership degree of the second level index fall into the V risk level is obtained, The relative membership degree of each secondary index is represented by P matrix, there are:

$$p_i = \begin{bmatrix} p_{i1} \\ p_{i2} \\ \vdots \\ p_{ij} \end{bmatrix} = \begin{bmatrix} p_{i11} & p_{i12} & \cdots & p_{i15} \\ p_{i21} & p_{i22} & \cdots & p_{i25} \\ \vdots & \vdots & \cdots & \vdots \\ p_{ij1} & p_{ij2} & \cdots & p_{ij5} \end{bmatrix} \tag{6}$$

2.3.3 The Relative Membership of Grade U_i.

A represents the relative membership degree of each level evaluation index, there are: $A_i = X_i \bullet P_i = [c_{i1} \quad c_{i2} \quad \cdots \quad c_{i5}]$, Here $c_{ij} = \sum_{j=1}^{n_i} \beta_{ij} p_{ij}, i = 1,2,\cdots,5$. n_i Is the number of second level index belong to first level index of i .The degree of relative membership of the risk level V of the ship's safety risk level is:

$$A=\begin{bmatrix} A_1 \\ A_2 \\ M \\ A_5 \end{bmatrix}=\begin{bmatrix} c_{11} & c_{12} & \Lambda & c_{15} \\ c_{21} & c_{22} & \Lambda & c_{25} \\ M & M & \Lambda & M \\ c_{51} & c_{52} & \Lambda & c_{55} \end{bmatrix} \tag{7}$$

2.3.4 Method of Comprehensive Evaluation.

The primary index weight X times the relative membership A, the safety risk of ship belongs to the evaluation value of each risk level can be acquired

With T tag, there are $T = X \bullet A = [T_1 \quad T_2 \quad \Lambda \quad T_5]$, in the formula $T_v == \sum_{i=1}^{5} a_i c_{ij}$, and then the risk rating of T times the risk level $V = [v_1 \quad v_2 \quad \Lambda \quad v_5]$, the ship risk rating can be obtained, with G tag, there are $G = S \bullet V^T$, The magnitude of the risk level determines the risk level of the ship, And take corresponding preventive measures accordingly. [4]

3. Examples

Take a ship for example, risk assessment of its security status according to the above ship safety risk index system and analytic hierarchy process principle. The investigation was carried out by 12 ship safety experts, gather data from the survey, calculate and the weight set of the primary evaluation index is determined respectively.

$X = [0.2324 \quad 0.2413 \quad 0.1277 \quad 0.1780 \quad 0.2206]$

Secondary evaluation index weight set as X_i

$X_1 = [0.5325 \quad 0.1440 \quad 0.3235]$

$X_2 = [0.1563 \quad 0.2550 \quad 0.2028 \quad 0.2132 \quad 0.1727]$

$X_3 = [0.1783 \quad 0.2426 \quad 0.2234 \quad 0.2015 \quad 0.1542]$

$X_4 = [0.3036 \quad 0.3124 \quad 0.1935 \quad 0{,}1905]$

$X_5 = [0.2436 \quad 0.2615 \quad 0.2503 \quad 0.2554]$

A sample matrix D was obtained by selecting five leading experts from 12 experts to grade the safety evaluation of the ship.

$$D=\begin{bmatrix} 2.5 & 3 & 3 & 2.5 & 2.5 \\ M & M & M & M & M \\ 2.5 & 3 & 2.5 & 2.5 & 3 \\ M & M & M & M & M \\ 3 & 3 & 2.5 & 3.5 & 3.5 \end{bmatrix} \tag{8}$$

The relative membership degree of the first grade evaluation index of the ship can be obtained by using the above two indexes and the relative membership degree of the first level index.

$$A=\begin{bmatrix} A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \end{bmatrix}=\begin{bmatrix} 0 & 0.2934 & 0.3536 & 0.2804 & 0.1726 \\ 0 & 0.3036 & 0.3436 & 0.2716 & 0.1812 \\ 0 & 0.3017 & 0.3423 & 0.2814 & 0.1746 \\ 0 & 0.2994 & 0.3382 & 0.2891 & 0.1733 \\ 0 & 0.3012 & 0.3493 & 0.2782 & 0.1713 \end{bmatrix} \tag{9}$$

$T = X \bullet A = [0 \quad 0.2999 \quad 0.3461 \quad 0.2794 \quad 0.0748]$

$G = T \bullet V^T = 3.1297$

From the evaluation results, the ship is at a higher risk level, Preventive measures should be strengthened in particular, the safety risk of second-level indicators of safe operation and management level of the first level index is generally high, the ship management level should be strengthened in the future in addition, the ship's five levels are at a higher risk level, the low risk level is 0. [5]

4. Conclusion

Ship safety is an extremely important role in the normal operation of the ship, it is very important to evaluate ship safety risk, by using the method of analytic hierarchy process and grey clustering method, it is not only accurate to grasp the ship safety risk, but also adapt to the ship's safety risk characteristics. Therefore, the evaluation method has certain practical value.

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