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Analysis and Evaluation of Navigation Safety of Super Large Oil Tanker Entering and Exiting the Yangtze River Shanghai Section

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Abstract

The Yangtze Estuary Deepwater Channel is also known as the North Channel. The daily average ship flow exceeds hundreds. With the large-scale development of the shipbuilding industry, it is normal for the Super Large Oil Tanker (VLCC) to frequently enter and exit the Yangtze Estuary Deepwater Channel. Density, water depth, channel width and tidal water have great impact on the safety of super large oil tankers. Choosing the right traffic flow time period and tidal flow in and out is very important for the safety of super large oil tankers. The navigation safety of the deep water channel of the Yangtze River estuary is complicated, and the super large oil tanker enters and exits. The Yangtze River deep-water channel needs to meet the relevant safety characteristics. Based on the traffic flow, tide and ship maneuverability of the Yangtze Estuary deep-water channel, this paper uses the fuzzy synthetic evaluation method to analyze the safety of the super large tanker entering and leaving the Yangtze Estuary deep-water channel. The super large tanker must The Maritime Safety Administration is notified to enter the port in coordination to ensure the safety of ships and waterways [1].

Keywords

Yangtze Estuary deep water channel, navigation safety , fuzzy synthetic evaluation.

1. Preface

The large-scale tanker entering and leaving the Yangtze River Shanghai section is mainly composed of the Yangtze Estuary North Channel, Waigaoqiao Channel, Baoshan Channel, and Baoshan North Channel. Some of these vessels also include the use of Xin qiao Passage and Xinqiao Waterway due to business needs to Chong Ming. Da Dong Shipyard.

The Yangtze River estuary deepwater channel is the golden waterway throat of today, which is related to the country's economic development. With the rapid advancement of the “Yangtze River Economic Belt” and the “One Belt, One Road” national strategy, the flow of import and export vessels in the Yangtze Estuary deepwater channel has soared, daily average The flow rate of ships has increased, especially with the frequent entry and exit of the super-large cruise ships into the Yangtze River channel. The navigation waters of the navigation channels are severely restricted, and the navigation risks of large ships have soared [2]. The intensive ship traffic flow has brought huge impact to the Yangtze Estuary deep-water channel. Security risks. Zhou Wei et al. analyzed the probability of super-wide intersection navigation in the deep water channel of the Yangtze River estuary and used Arena simulation analysis to obtain the result [3]. Safety assessment of the safety of super large cruise ships in and out of the Yangtze Estuary deep water channel. The safety assessment methods include: analytic hierarchy analysis, fuzzy analysis, and neural network analysis. Fang Quangen and Hu Shengping analyzed the safety assessment of the restricted waters of Shanghai Port through FSA, and did not conduct a safety assessment for the navigation of the Shanghai section of the Yangtze River estuary for large super tankers [4]. This paper will evaluate the safety of large-scale oil tankers entering and

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leaving the Yangtze River Shanghai section; using the easy-to-analyze and structural logic algorithm for comprehensive evaluation, namely "fuzzy synthetic evaluation method". Finally, an example analysis finally demonstrates the feasibility of safe navigation of the super large oil tanker entering and leaving the Yangtze River Shanghai section.

2. Analysis of Safety Factors of Large Super Type Ships Entering and Exiting the Yangtze River Shanghai Section

2.1. Channel Width Suitability

The large super oil tanker enters and exits the Yangtze River Shanghai section and is a ship alignment route. The water depth of the chart is 12.5m, the width of each channel is different, and the traffic volume of the ship is large, so the safety of each segment is different.

1) Channel width requirement

According to the Requirements of the "Seaport General Design Code"(JTS 165-2013), the relevant elements of the voyage channel width are calculated as follows:

$$W_{\text{side}} = A + 2C$$

$$\text{A} = n(L\sin\gamma + B)$$

W_{side}— one-way width of the required channel (m);

A—track tape width (m);

C—the rich width (m) between the ship and the bottom line of the channel, the tanker, the speed of the ship is greater than 6 knots, and the design ship width B is 1.5 times;

n—the ship drift multiple, cross wind ≤ 7 levels, cross flow 0.25 m / s < V ≤ 0.50 m / s, take 1.69;

r—wind, flow pressure declination (°), the actual calculation takes 7 °;

L—Design captain (m);

B—design ship width (m);

2) Yangtze River Estuary deepwater channel super widening meeting

According to the provisions of Article 22 of the "Administrative Measures for the Safety of Deepwater Channels in the Yangtze River Estuary (Trial)", the super widening meeting is mainly applicable to the ultra-wide-crossing meeting between large heavy-duty container ships and large cruise ships. The VLCC is 40m wide and is not applicable large-width. Therefore, it is only possible to meet with ships with a ship width of ≤ 20m. According to the "Seaport General Design Code", the required one-way channel width is 350m, and the effective width of the Yangtze Estuary deep-water channel is 350m. It can only meet the VLCC type 40m wide single-ship navigation, and it is not allowed to meet with other ships [5].

2.2. Navigation Standards and Traffic Flows of the Shanghai Section of the Yangtze River Deep Water Channel

2.2.1. Navigation Standard for the Shanghai Section of the Yangtze River Deepwater Channel

"Northern Channel Deep-water Channel" refers to the channel between the west boundary line of the A warning zone of the Yangtze River estuary and the east boundary line of the YuanYuansha warning zone, with a total length of about 43 miles. The deep water channel bottom width maintenance depth is 12.5 meters below the theoretical minimum tide surface, and its boundary line is marked by the virtual AIS navigation mark. The extension of the Yangtze Estuary deepwater channel is located in the Waigaoqiao Channel , Baoshan Channel and Baoshan North Channel, and its boundary is marked by the virtual AIS navigation mark. The extension of the Yangtze Estuary deepwater channel for large vessels with an actual draft of

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more than 7 meters is required to "Administrative Measures for the Safety of Deepwater Channels in the Yangtze River Estuary (Trial)" and the "Seaport General Design Code".

The deepwater channel of the Shanghai section of the Yangtze River is the only channel for large-scale heavy-duty vessels to enter and exit the Yangtze River. It is planned to meet the full-scale 50,000-ton container ship (11.5m of actual draught), and the 50,000-ton bulk carrier is fully loaded with two-way navigation. The 10,000-ton ocean-going container ship and the 100,000-ton full-load bulk carrier and the 200,000-tonne-loaded bulk carrier are used for tidal navigation. According to statistics, since the official completion in 2010, the navigation depth guarantee rate of the entire 12.5 m deep water channel is above 95%.

2.2.2. Channel Traffic Flow

The large-scale oil tanker entering and leaving the Yangtze River Shanghai section is mainly composed of the Yangtze Estuary North Channel, the Waigaoqiao Channel, the Baoshan Channel, and the Baoshan North Channel. The traffic flow of each section has different impacts on navigation safety, and the risk impact factor is positive Growth.

1) North channel of ship flow

Statistics of the import and export flow of the Yangtze Estuary deepwater channel from April 2017 to April 2018: the average daily import and export flow of the Yangtze Estuary deepwater channel was 192.9 times, of which 114.39 were imported and 78.55 were exported Fig 1.

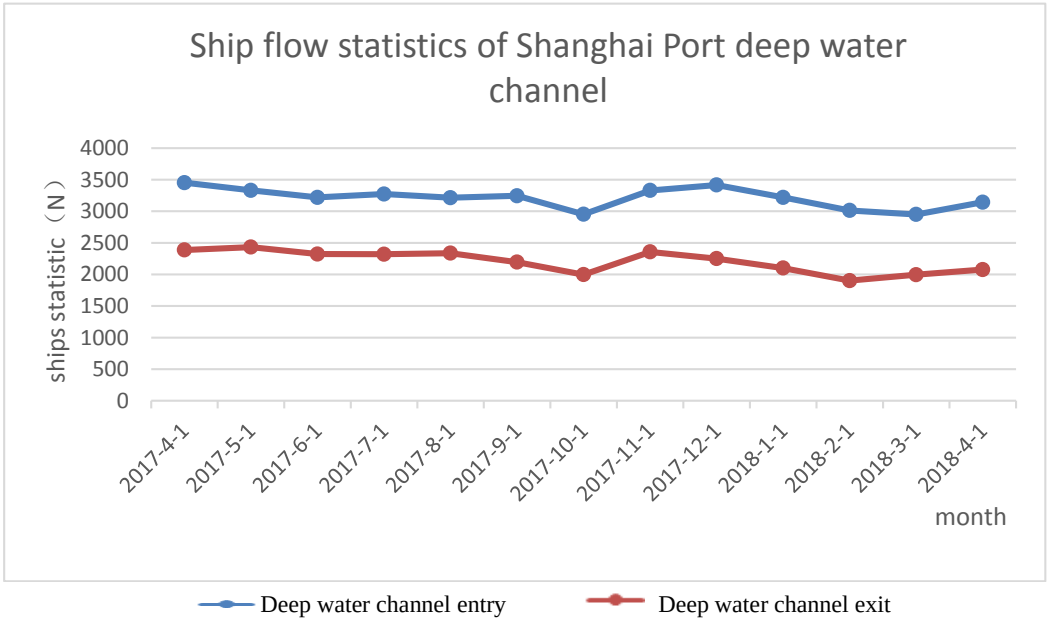

Fig 1. Ship flow statistics of deep water channel from April 2017 to April 2018

The design of the deep-water channel has taken into account the 100,000-200,000-ton bulk carrier, the safety of the 200,000-tonne ship entering and leaving the deep-water channel poses great challenges. At present, the ship type of the Yangtze River estuary with a width of more than 40 m or over 275 m is mainly 7W and above container ships, 100,000-ton and above bulk carriers, large cruise ships and a small number of special ship types. According to the AIS traffic statistics, it can be seen from Fig.2 that from April 2017 to April 2018, ships with a ship width of more than 40 m remain at around 540 per month, and ships with a ship length of over 275 m remain at 530 per month. Around the boat.

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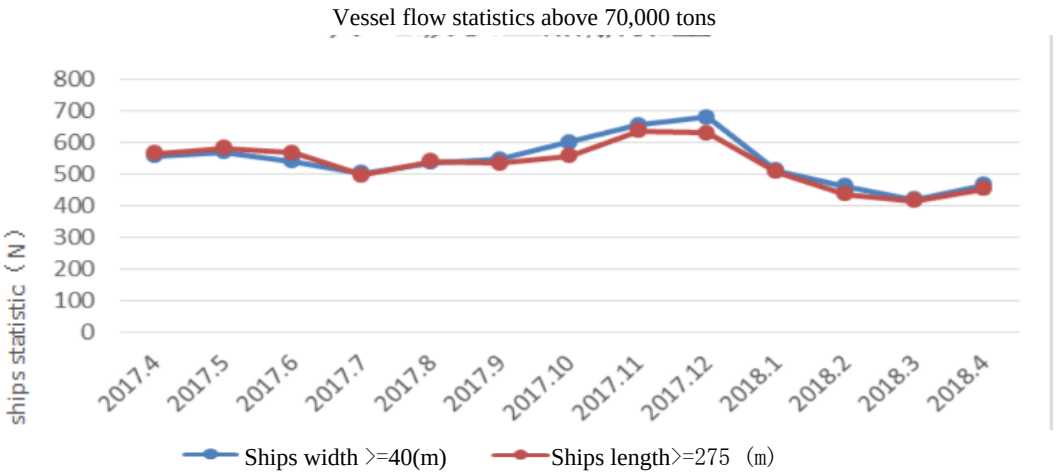


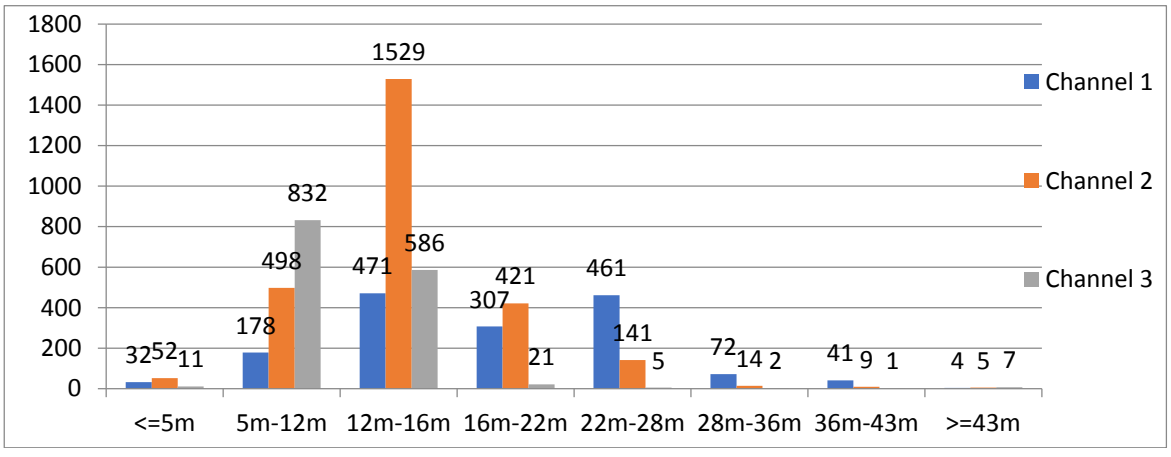
Fig 2. Super-ship width and super long ship flow statistics from April 2017 to April 2018

2). The flow of ships in the Waigaoqiao channel

According to the statistics of AIS traffic data, 2.5 hours before the climax of Changxing and 0.5 hours after the climax of Changxing, the density of ships in the river surface of Waigaoqiao is quite large, and the average flow of ships per day and night is observed hundreds of times. In addition, the daily entry and exit of the Waigaoqiao Wharf has more than 10 times. The large container ships of the international routes are off the dock, and the container ships of the inner branch lines of about 30 times are located off the dock. There are also dangerous goods such as chemicals from the China Shipping Group Ship Sewage Treatment Plant Terminal, Dongfang Storage Tank Company Terminal, and liquefied gas, as well as large oil tankers from the Zhonghai Seaside Oil Depot Terminal and Waigaoqiao Refinery Wharf.

3). Baoshan Channel Ship Flow Situation

According to the 7-day ship flow statistics, the Baoshan channel can be divided into channel 1, channel 2, channel 3 (Baoshan branch channel). The distribution of the captains of each channel is shown in Figure 3. In channel 1, 12m-16m and 16m- The 22m long ship has the most. Among the channel 2, the largest number of ships of 12m-16m length is 1,529 ships, and the number of ships with a length of 5m-12m is the largest among the 3 channels. After the statistics of ships of 40m and above within 7 days, the monthly average number is about 288, with an average daily rate of 9.6. According to the “Seaport General Design Code”, the super-large ship can only sail on a single ship at this time.



Ships width m

Figure 3.

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4). analysis of traffic flow in Baoshan North Channel

The Liuhekou warning zone of Baoshan North Channel is the junction of two imported ship flows from Baoshan North Channel and Baoshan South Channel. 2 to 3.5 hours after the low tide of Shidongkou, there is a small vessel imported from Baoshan South Channel. After arriving at Baoshan Dengfu, it will cross the Liuhekou warning zone to the right and enter the Baishuisha North Waterway from the west exit of Baoshan North Channel. , drove into the river. It has a great influence on large ships entering and exiting the north exit of Baoshan North Channel and Baoshan North Channel during this period.

2.3. The in Flu of Tides and Trend on the Water Depth of the Channel

2.3.1. Tides

The Yangtze River estuary is a medium-intensity tidal estuary. The normal half-day tide is outside the mouth. The tidal wave deformation in the mouth is an irregular half-day shallow sea tide. The tidal wave deformation degree is larger toward the upstream, resulting in changes in tidal level, tidal range and tide time. There were two ups and downs in one day, and the average rise and fall lasted about 12 hours and 25 minutes. Every year from spring equinox to autumn, it is divided into night tides, and the autumn equinox to the next spring is divided into large tides. The highest tide level generally occurs in August to September, and is often the result of the combined effect of astronomical tides and typhoons.

2.3.2. Trend

(1) There are two main locations in the Yangtze River estuary and the north sag.

A. The surface layer between the north channel of the Yangtze River estuary and the channel of the south channel surges to 300°, the flow rate is 1.35m/s; the average flow of the vertical line is 300.6°, and the flow rate is 1.16m/s. The surface layer rushed to 086.5°, the flow rate was 1.31 m/s; the average flow of the vertical line was 087.3°, and the flow rate was 1.14 m/s.

B. Trend near the Yangtze River estuary

In the Yangtze Estuary deep water channel D14 ~ D16 lights floating outside the water flow is still 360 ° clockwise rotation, see Table 1 to Table 4.

Table 1. List of flow patterns near the Yangtze River light boat (direction / degree, speed/ kn)

	Before the high tide of Changxing					High tide	After the high tide of Changxing					
	5h	4h	3h	2h	1h		1h	2h	3h	4h	5h	6h
Direction	230	240	259	273	291	335	069	084	095	108	124	151
Speed	1.3	1.7	2.2	2.0	1.4	0.7	1.0	2.0	2.3	2.0	2.0	1.7

Table 2. List of flow diagrams near D6 lamp float (Direction / degree, Speed/ kn)

	Before the high tide of Changxing					High tide	After the high tide of Changxing							
	5h	4h	3h	2h	1h		1h	2h	3h	4h	5h	6h	7h	7.5h
Direction	238	252	261	270	283	318	061	077	085	092	108	144	221	238
Speed	1.3	1.7	2.2	2.0	1.4	0.7	1.0	2.0	2.3	2.0	2.0	1.7	1.6	2.3

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Table 3. List of flow patterns near the D11/D12~D13/D14 lamp float (Direction/degree,Speed/kn)

	Before the high tide of Changxing					High tide	After the high tide of Changxing							
	5h	4h	3h	2h	1h		1h	2h	3h	4h	5h	6h	7h	LW
Direction	113	291	288	292	297	302	301	111	113	113	113	113	113	113
Speed	1.7	0.7	2.5	3.6	3.5	2.4	0.7	1.5	2.3	4	4	3.6	2.6	1.7

Table 4. Near the round light ship (Direction / degree, Speed/ kn)

	Before the high tide of Zhongjun						High tide	After the high tide of Zhongjun							
	5h	4.5h	4h	3h	2h	1h		1h	2h	3h	4h	5h	6h	7h	LW
Direction	142	148	145	144	325	321	319	326	337	080	123	136	141	140	140
Speed	2.9	3	2.8	2.3	2.2	3.1	2.2	1.9	0.5	0.5	1.4	2.9	2.9	3.0	3.0

It can be seen from the average flow velocity vector of each measurement station that the stations are basically reciprocating near the stations, and the ups and downs are relatively consistent. The flow of the fluctuations is basically consistent with the mainstream trend. The falling tide velocity is greater than the rising tide velocity, and the falling tide duration is greater than the rising tide duration. The maximum flow velocity appears in the upper layer of the water body. The average maximum velocity of the vertical line of the ebb tide is 2.92 m/s, the average maximum velocity of the vertical line of the tide is 2.20 m/s. Look, the speed of the flood season is faster than the speed of the dry season, and the speed of the rising tide is not much different.

(2) The situation of the Waigaoqiao channel

In this region, the tidal current velocity is basically greater than the tidal current velocity, and the fluctuation trend is relatively concentrated, showing a NW-SE reciprocating flow. The specific flow velocity of each measurement point also has a certain relationship with the terrain position. The flood season is faster than the dry season, and the flood season is slightly slower than the dry season. The water flow situation near the Waigaoqiao channel is shown in Table 5.

Table 5. List of flow patterns near the Waigaoqiao channel (Direction / degree, Speed/ kn)

	Before the high tide of Changxing					High tide	After the high tide of Changxing							
	5h	4h	3h	2h	1h		1h	2h	3h	4h	5h	6h	7h	LW
Direction	110	118	305	303	305	308	296	123	120	123	105	107	104	105
Speed	1.75	1.11	0.94	1.98	1.81	1.41	0.36	0.55	1.42	1.90	1.98	2.13	1.99	1.89

The flow velocity in the water near the south side of the NO.4 anchorage outside Wusongkou of Waigaoqiao Channel: 2h after the low tide of Changxing, 2h after the Changxing high tide; the

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maximum flow velocity is 4.1 knots (6h after Changxing orgasm), the maximum flow velocity Section 3.8 kn (2h before the high tide of Changxing).

(3) Current situation of Baoshan North Channel (Shidongkou is base station)

The flow direction of Baoshan North Channel is basically parallel with the heading. At the vicinity of No. 81 lamp float, there is a trend flowing to the Xinqiao channel when it falls, and a trend is down the Baoshan North Channel.

The situation of the tidal level of the base station is as follows:

Highest tide level	6.23m
Minimum tide level	0.24m
Average high tide level	3.54m
Average low tide level	1.36m
Average tidal range	2.20m
Maximum tidal range	4.42m

3. Correlation Between Super Large Cruiser Handling Performance and Navigation Safety

3.1. Analysis of Maneuvering Motion Equation of Large Super-type Ship Oil

According to the ship type and tonnage, the ship's first-order equation linearization parameters are different. It is usually used in ships with fixed tonnage range to determine the ship's maneuverability. The VLCC-type ship motion equation established by processing quantitative data is as follows;

$$\begin{cases} (m - Y_{\dot{V}})\dot{V} - Y_v v + (mx_G - Y_{\dot{r}})\dot{r} + (mu_1 - Y_r) = Y_\delta \delta \\ (mx_G - N_{\dot{V}})\dot{V} - N_V V + (I_z - N_{\dot{r}})\dot{r} + (mx_G u_1 - N_r) r = N_\delta \delta \end{cases}$$

$\dot{v}, v, \dot{r}, r, \delta$ is ship type parameters. When the ship's maneuvering motion is slow, the high-order small amount can be neglected. According to the above ship maneuvering equation, the ship's distance, parking stroke, steering, and cycle can be evaluated to determine the ship's maneuverability [6].

3.2. Analysis of Navigation Factors of the Super-type Tanker in the Shanghai Section of the Yangtze Estuary

When the Large-scale oil tanker sails in the Shanghai section of the Yangtze River, due to the influence of the width, current and traffic flow of the channel, especially the large-scale ships must be familiar with the hydrology and traffic flow of the navigation channel. When the tanker enters the Shanghai section of the Yangtze River, especially round The current trend of the light ship and the Waigaoqiao channel is the most complicated, and it should be rigorously sailed. According to the “Administrative Measures for the Safety of Deepwater Channels in the Yangtze River Estuary (Trial)”, the Maritime Safety Administration must be notified to make relevant regulations and coordinate the dredging of the ship traffic flow in compliance with relevant regulations. Under the conditions, you can enter and exit the Yangtze Estuary deep water channel.

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4. Application of Fuzzy Synthetic Evaluation Algorithm in Safety Assessment of VLCC Entering and Exiting the Yangtze River Shanghai Section

4.1. Introduction to Fuzzy Synthetic Evaluation Model

The boundaries of many things are not very obvious. It is difficult to attribute them to a certain category in the evaluation. So we first evaluate the single factor and then comprehensively evaluate all factors to prevent the loss of any statistical information and information. It helps to solve the problem of deviation from the deterministic evaluation of "yes" or "no".

1).Fuzzy Synthetic Evaluation to construct judgment matrix and determine weight

According to the analysis of fuzzy synthetic evaluation method, firstly, the single factor focusing on the concentration of factors u_i ($i = 1,2,3 \ldots, m$)As a factor judgement, from the factor ui, focus on the matter v_j ($j = 1,2,3 \ldots n$)The degree of membership is r_{ij}, which leads to the single factor evaluation set of the i-th factor U_i:

$$r_{i=}(r_{i1}, r_{i2}, \ldots r_{in})$$

Such an evaluation set of M focus factors is constructed as a total evaluation matrix R. That is, each evaluated object determines the fuzzy relationship R from U to V, which is a matrix:

$$R = (r_{ij})_{m\times n} = \begin{bmatrix} r_{11} & r_{12} & r_{13} \ldots. & r_{1n} \\ r_{21} & r_{22} & r_{23} \ \ldots & r_{2n} \\ \ldots & \ldots & \ldots \ \ \ldots & \ldots \\ r_{m1} & r_{m2} & r_{m3} \ \ldots & r_{nm} \end{bmatrix}$$

Where r_{ij} indicates that from the factor u_i, the object of the evaluation can be rated as the degree of v_j (i = 1, 2, ..., m; j = 1, 2, ..., n). Specifically, r_{ij} represents the frequency distribution of the i-th factor $u_i$on the j-th comment v_j, which is generally normalized so that it satisfies the formula $\sum r_{ij} = 1$.

2).analysis and determination of weight method

Each factor in the evaluation factor has different status and role in the “evaluation target”, and the proportion of each factor is different. The weight of the common evaluation questions is generally subjective and more subjective; under some conditions, subjective Determining the weight has an objective side, reflecting the actual situation to a certain extent and has a high reference value. The amount of importance of each element in the set of U in the subjective weighting is represented by the fuzzy weight vector on the factor set U. A=$(a_1, a_2, a_3 \ldots a_m)$ The other type is the fuzzy relationship on U × V, which is expressed as m × n fuzzy matrix R. Both types of fuzzy sets are reflected in the preference structure.

4.2. Case Analysis and Steps of Fuzzy Comprehensive Evaluation of Super Large Tanker Yangtze River Shanghai Segment

(1). Fuzzy comprehensive evaluation factor set

Based on the influence of VLCC type ship scale and traffic flow, the restricted water area width of the Yangtze River channel is different, and the safety factors of the VLCC type ship entering and leaving the Yangtze Estuary deep water channel can be summarized as follows [7]. Therefore, the factor set is:

U= {vehicle traffic flow, tides, ship maneuverability, crew maneuvering skills}

(2). Establish an evaluation set for comprehensive evaluation

The purpose of the comprehensive evaluation: to understand the safety of the VLCC type ships entering and leaving the Yangtze Estuary deep water channel, therefore, the evaluation set should be:

V={conservative, aggressive, safe}

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(3). Perform single-factor fuzzy evaluation and obtain the evaluation matrix R.

Starting from the above various factors alone, after expert analysis, Through the statistics of ship traffic safety and navigation for the large and super-type ships entering and leaving the Yangtze River Shanghai section in 2018,according to "Administrative Measures for the Safety of Deepwater Channels in the Yangtze River Estuary (Trial)"and "Seaport General Design Code" combined with expert analysis, the evaluation of the weights of the super-large oil tankers entering and leaving the Yangtze Estuary deep-water channel is judged as a single factor evaluation set.

$$R_1 = (0.4,0.2,0.4)$$
$$R_2 = (0.5,0.1,0.4)$$
$$R_3 = (0.35,0.15,0.5)$$
$$R_4 = (0.3,0.1,0.6)$$

The judgment matrix is:

$$R = \begin{bmatrix} 0.4 & 0.2 & 0.4 \\ 0.5 & 0.1 & 0.4 \\ 0.35 & 0.15 & 0.5 \\ 0.3 & 0.1 & 0.6 \end{bmatrix}$$

(4). Establish an evaluation model and conduct comprehensive evaluation.

For the VLCC type deepwater channel navigation, due to different ship scales and ship maneuverability, the traffic flow of the channel varies with time, and the weight of each factor can be determined as follows:

A= (0.35, 0.2, 0.3, 0.15)

The evaluation model is: B=A*R

$$= (0.35, 0.2, 0.3, 0.15)*\begin{bmatrix} 0.4 & 0.2 & 0.4 \\ 0.5 & 0.1 & 0.4 \\ 0.35 & 0.15 & 0.5 \\ 0.3 & 0.1 & 0.6 \end{bmatrix}$$

= (0.39, 0.15, 0.0.46)

According to the Fuzzy Synthetic evaluation B=(0.39,0.18,0.43.It can be concluded that when VLCC ships enter and exit the Yangtze Estuary deep water channel, 39% of the ships are conservative, 46% are safe, and only 15% are risky.

5. Conclusion

By analyzing the traffic flow, channel width, and tidal current factors of the Yangtze River Shanghai section, combined with the maneuvering performance characteristics of super-large ships. The equations of motion of super large oil tankers entering and leaving the deep water channel of the Yangtze River estuary are analyzed. Finally, the fuzzy comprehensive evaluation method is used to analyze the three states of the super large oil tanker entering and leaving the Yangtze Estuary deep water channel, which are "conservative", "adventurous" and "safe". It can be concluded that 85% of the super-large cruise ships are more conservative and conservative, in line with the requirements of the "Administrative Measures for the Safety of Deepwater Channels in the Yangtze River Estuary (Trial)", so the evaluation and analysis of super large tankers can safely enter and exit the Yangtze Estuary deep-water channel, extending the blur. The fuzzy synthetic evaluation method is applied to the safety assessment of super large ships in navigation.

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