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Marine Traffic Real-Time Safety Index

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ABSTRACT: To reflect the safety degree of marine traffic in real-time and intuitively, this paper put forward a concept of real-time safety index of marine traffic, established marine traffic real-time safety index system, and constructed a real-time safety index evaluation model by using vessel traffic and navigation environmental data provided by shore-based AIS base station network, and quantifying a variety of data which impacts the safety of marine traffic such as ships' real-time dynamic data, weather changes and so on. A continuous real-time evaluation to a specific area was carried out in the form of real-time index curve, taking the Waigaoqiao Channel of Port Shanghai as an example, to verify the feasibility and effectiveness of marine traffic real-time safety index.

1 INTRODUCTION

Traditionally, maritime authorities usually make use of number of deaths, accidents, wrecks, economic loss etc. as evaluation index of marine traffic safety. These are mainly statistical analysis on evaluation factors in the waters over a period of time, of which the results are static, and lack of real-time, process control and management. It is unable to reflect the safety situation in real-time. To be able to directly reflect the real-time degree of safety in waters, we established a complete maritime vessel traffic safety evaluation index system, and quantified the results of the safety evaluation in navigable waters. it is crucial to provide intuitive real-time evaluation results for marine safety personnel.

With the rapid development of information technology, the major shipping countries in the world gradually established a more complete shore-based AIS networks for busy waters, which can monitor marine traffic conditions in real-time, and acquire a variety of safety data affecting marine traffic such as ships' movement, weather conditions and so on. These real-time data provide a basic guarantee for marine traffic safety index. Lots of researches on marine navigation safety have been conducted by many scholars and marine safety study is shifted gradually as well from static to dynamic analysis of real-time processing research. Currently, in the relative field of marine navigation safety, in the paper[1], the author put forward the concept of a tentative real-time safety index, established a real-time safety evaluation index system, and more considerations of the environmental impacts on navigation safety were given, including some relatively fixed, rarely changing factors, but the dynamic nature of the evaluation results is not so strong. In the paper [2], the author analysed navigation safety factors, and utilized a fuzzy and comprehensive evaluation method to build a more complete navigation environment safety evaluation index system, and select a group of experimental data to demonstrate its feasibility. However, not all indicators selected had the characteristics of real-time changes and the required data was obtained with great difficulty.

The concept of marine traffic real-time safety Index (abbreviated as MTRSI) proposed in this paper is a dynamic safety value that through the establishment of navigational safety evaluation index system, quantify relative parameters affecting marine navigation safety, evaluate the situation by using relative safety evaluation method, and display the evaluation results in form of index.

To achieve MTRSI, three basic steps shall be followed:

1 Establish different evaluation index system as per different needs;
2 Choose different safety evaluation methods as per evaluation purpose;
3 Display evaluation results in the form of index and publish through Internet, at the meantime, publish through internet the real-time information of each index to facilitate the inquiry and decision.

2 MODEL OF MTRSI

MTRSI is a real-time index that reflects real-time safety condition in specific waters, which is a complex model and of which many factors are very difficult to be described using traditional mathematical models. Thus, according to the principles of evaluated object features and evaluation methods, comprehensive scoring method is selected as final calculation. Algorithm process is shown in Fig. 1.

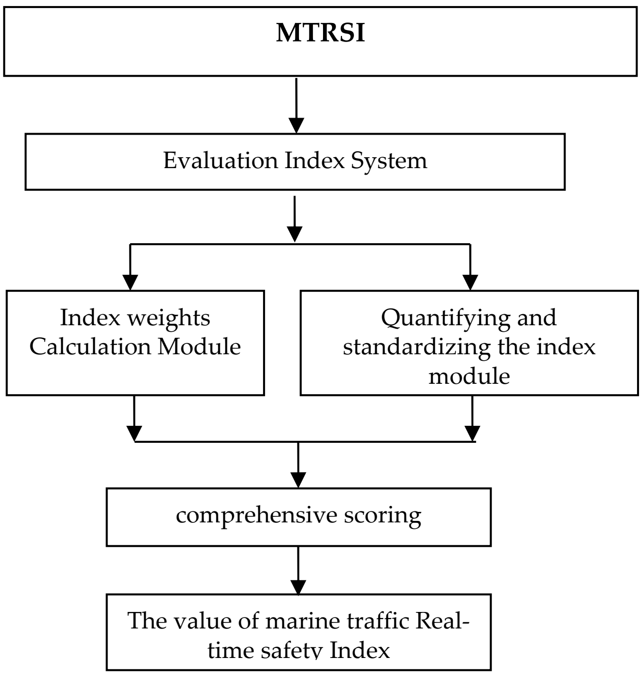

Figure 1. Marine traffic real-time safety index data model

The selection of comprehensive scoring method is mainly based on the following four points:

1 Determine the appropriate index of real-time evaluation model according to investigation and expert advice ;
2 For determining the value of each index, select the appropriate method of calculating the value of quantitative index;
3 Consider using a weighted sum score for each safety index contribution differences;
4 Use comprehensive scoring method to display the evaluation results in value.

3 ESTABLISHMENT OF SAFETY EVALUATION INDEX

MTRSI varies over time in the evaluation of the model system. The evaluation index is not the more the better, the key lies in the contribution of evaluation results.

3.1 *select evaluation index*

Many factors affect marine traffic safety. They are divided into relatively static factors such as channel facilities in a certain period, anchorages, berths and other factors etc., and real-time dynamic factors, such as collision between ships, natural conditions, visibility etc. In this article, we preferred to choose those indexes that may occur in real-time and short-term as an evaluation index.

We select indexes as few as possible to reflect objectively the marine navigation safety. Through consultation with specialists and field investigation, we analysed and summarized the prime key indexes that changes may occur in real-time and short-term, and eventually established the effects of marine traffic in real-time safety index which are 4 primary indexes and 5 secondary indexes. Marine traffic safety indexes affecting marine real-time safety are mentioned in Table 2.

Table 2. Marine traffic real-time safety index analysis

Primary index	Secondary index
Ship traffic conditions	Ships difference Ships encounter rate
Natural Environment	Leeway and drift angle Visibility Diurnal variation
Emergencies	Collision, grounding, out of Control etc
Dangerous cargo ships	Chemical Tanker, LNG, LPG etc

3.2 *Obtain and calculate index weights*

To obtain index weight, firstly design the questionnaire according to classification and requirements, and then use AHP method to constitute judgment matrix according to the questionnaire. Each index weight is calculated by judgment matrix. Do the above process to all questionnaires and calculate the index weight vector that all experts assigned, and then after the weight vector anomaly detection , average all detection passed weight vectors ,and finally obtain the weight of each index values as is shown in Table 3.

Table 3. Index weight values

Index Code	index name	Weight Values (w_i)
Index 1	Ship traffic condition	0.3315
Index 2	Natural Environment	0.3013
Index 3	Emergencies	0.1894
Index 4	Dangerous cargo ships	0.1778
Index 5	Ships difference	0.2601
Index 6	Ships encounter rate	0.7399
Index 7	Leeway and Drift angle	0.2993
Index 8	Visibility	0.3996
Index 9	Diurnal variation	0.3011

4 ANALYSIS OF MTRSI

Selecting appropriate index calculation can grasp index changing trend intuitively and clearly. Once MTRSI abnormally changes, the reason can be analysed through the changes of MTRSI.

4.1 *Difference of ships*

Difference of ships means manoeuvrability is different between vessels of different scale, and time requirement of action to avoid collision is different as well. Generally, navigational officers on large vessels navigate vessels in comply with relative regulations, while navigational officers on small vessels tend to navigate at random. Traffic environment in fairways will be very complex, and risk ship collision will increase. The mean square difference (m) of ship's length as the value of ship's difference can be calculated by formula (1):

$$\overline{L} = \frac{1}{n}\sum_{i=1}^{n} L_i \qquad m = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(L_i - \overline{L})^2} \tag{1}$$

4.2 *Ships encounter rate*

In this paper, we take use of the Goodwin's theory of Ship Safety Domain and calculation of Ships encounter rate in paper[3].Considering not only the current time the ship will encounter state, but also taking into account the situation of the ships encounter in the further time. When other ship enters the field of my own ship safe domain , recorded as one. Taking into account real-time capability of the MTRSI will be selected every five minutes as a time unit, collected ship data for few minutes as experimental base data. Set every five minutes for a time unit and denoted as 0,1,...,n, etc., and then average every time unit, denoted every five minutes for a time unit ,regard as 0,1, ..., 5. According to the above data, calculate the ship will encounter rate (M):

$$M = \frac{\text{TCPA（}E\text{）}}{\text{time of ship encounter risk（}S\text{）}} \tag{2}$$

$$E = \sum_i \left[1 * a_{i0} + \frac{5}{6}a_{i1} + \frac{4}{6}a_{i2} + \frac{3}{6}a_{i3} + \frac{2}{6}a_{i4} + \frac{1}{6}a_{i5} \right] \tag{3}$$

Where in formula 3, a_{ij} represents the number of ships encounter in the no. j time point of no. i time unit units that is expected to occur.

$$S = \text{Total number of vessels within every minute} \tag{4}$$

4.3 *Leeway and drift angle*

Leeway and drift angle is calculated by averaging the differences between COG and HEADING of all vessels in specific navigable waters.

4.4 *Visibility*

According to the relevant navigation regulations, when visibility is less than a specific value in narrow channels or in waters with heavy traffic, ship traffic control would be implemented or channel would be closed. In good visibility, officers on watch have a clear and wide vision, and it is easier for them to make correct decisions to navigate the ship more safely.

Table 4. Index calculation system (index value is within the range of interpolation process)

Primary index	Secondary index	Summary
Ship traffic conditions Index 1	Ships difference Index 5	Mean square error of Length of the ship (calculated according to existing historical statistics, to determine the minimum length of the ship are the variance is 32 and the maximum is 92)
	Ships encounter rate Index 6	According to Goodwin's Theory in paper [2], ship encounter rate calculation method to choose a designed waters based on historical data, the ship encounter rate within [0.02,0.4] interval.
Natural Environment Index 2	Leeway and Drift angle Index 7	According to course of advance and heading difference. The minimum value is 0°, the maximum value is 14°.
	Visibility Index 8	More than 10km defines as 1, less than 500m defines as zero.
	Diurnal variation Index 9	Time is between 0800 and1800 (daytime) the value is 1, and the remaining time (night) is 0.7, this index is not interpolated.
Emergencies Index 3	Collision, grounding, out of Control	No incidents the index value is one, more two sudden events is zero.
Dangerous cargo ships Index 4	Chemical Tanker, LNG, LPG	No dangerous ship is one, there are three or more dangerous ships is zero.

4.5 *Diurnal variation*

It is more dangerous to navigate the ship in night time compared with day time, due to dark light and interference of the background lights from land along the fairway, thus increasing difficulties of judgment of collision avoidance. Meanwhile, OOW is easy to fatigue at night, especially in the twilight hours which is accident-prone time, most people feel fatigue, and vision blurred.

4.6 *Emergencies*

Data of emergencies impacting navigational condition can be grasped according to emergencies, distress alert from fault vessel, navigational warnings and other information. When grounding, collision, and out of control and other emergencies occur in navigable waters, navigation conditions will change dramatically, prompt appropriate action shall be taken to prevent the situation from further deterioration.

4.7 *Dangerous cargo ships*

The presence of dangerous cargo ships can cause a restriction to vessels' action to avoid collision in entire navigable waters, and an effect on navigation order to some degree. And the overall shipping order will be affected.

In summary, scope of each index is determined through expert consultation, questionnaires, as well as the processing and analysis of historical data. The indexes related to water safety in real time, will be carried out within the value normalized to [0, 1].Calculation of the values of indexes is shown in Table 4.

Through analysing real-time indexes affecting marine traffic safety, combined with the above index values and weights, safety index values can be obtained by calculation in every one minute. Index value to determine marine traffic in real-time is calculated as following:

$$Index1 = \left(Index5 \times w_5 + Index6 \times w_6\right) \times 100$$

$$\mathrm{Index2} = \left(\mathrm{Index7} \times \mathrm{w}_7 + \mathrm{Index8} \times \mathrm{w}_8 + \mathrm{Index9} \times \mathrm{w}_9\right) \times 100 \quad (6)$$

MTRSI calculation formula is as following:

$$\mathrm{MTRSI} = \mathrm{Index1} \times \mathrm{w}_1 + \mathrm{Index2} \times \mathrm{w}_2 + \\ +\left(\mathrm{Index3} \times \mathrm{w}_3 + \mathrm{Index4} \times \mathrm{w}_4\right) \times 100$$

5 EXPERIMENT

In order to verify the suitability of MTRSI model, the 'Waigaoqiao' channel between 'Yuanyuansha' precautionary area to 'Wusongkou' precautionary area in Shanghai port were selected for this experiment.

5.1 *Examples of MTRSI*

The analysis was based on data from 1131LT to 1200LT on 27th, April, 2012. Each initial index value and the normalized value are shown in Table 5:

Table 5. Initial index value and normalized value (2012-4-27 11:31)

values index	Initial index value	Normalized index value
Ships difference	39.382463	0.877
Ships encounter rate	0.2918	0.2857
Leeway and Drift angle	0.081481	0.98836
Visibility	10	1
Diurnal variation	1	1
Emergencies	0	1
Dangerous cargo ships	0	1

MTRSI calculated result is 81.31 at 11:31 in comprehensive score method , and so on, MTRSI is calculated between 11:31 and 12:00 per minute, MTRSI exponential curve and the primary index values are shown in Figure 2, all values are between 0 and 100.

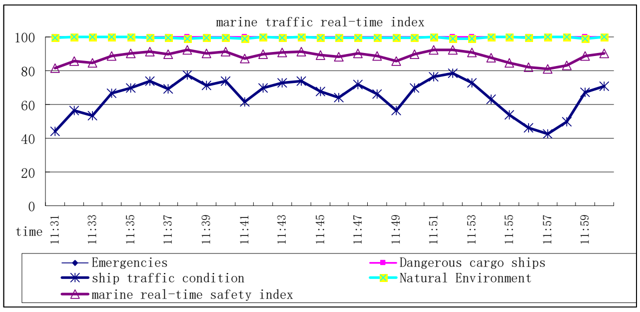

Figure 2. MTRSI and primary index values curve

In Figure 2, not only real-time fluctuations in MTRSI can be found, but also the index factors that mainly changed in this model, such as ship traffic conditions etc.

5.2 *MTRSI displaying*

Make use of calculation result of MTRSI model , demonstrate MTRSI within a particular time by Xml, MySql and Flex technology in Fig 3. The red area in Figure 3 is an area of high risk of collision, the value in the form index is the current MTRSI.

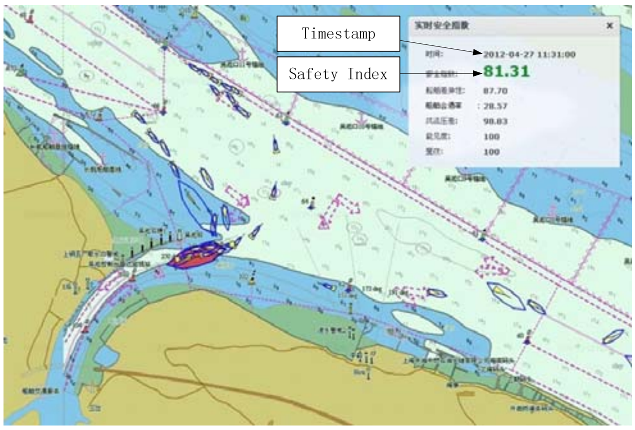

Figure 3. MTRSI displaying procedure interface

6 CONCLUSIONS

MTRSI can reflect directly marine traffic safety situation in port waters and the key channel in real time, at the same time it can be used not only as port safety produced reference, but also as a reference of marine traffic safety supervision. According to high risk area or high risk periods of marine traffic recognized by MTRSI model, marine authorities can increase marine enforcement forces and carry out traffic guidance and control timely. In addition, it can help shipping companies, port services and pre-arrival ships to keep abreast of port congestion and safety conditions in time so that they can make appropriate arrangement.

By tracking long-term MTRSI trend, we can analyse the changing trend and regularity of marine traffic safety in port waters and key channel, and MTRSI can be used to evaluate the effect of new marine safety management measures etc.

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