国家海洋信息中心
National Marine Data and Information Service

Research and Application of Environmental Risk Assessment Model for Marine Mobile Risk Sources

Authors/Presenter's name: Cao Shengwen
Email: 553986354@qq.com

Resume

- **Name:** Cao Shengwen
- **Education degree:** Master
- **Institution:** National Marine Data and Information Service
- **Country:** China
- **City:** TianJin

Research direction

- **Marine knowledge mining and marine information engineering research and design**
- **Participated in the research and development and demonstration of emergency technology for maritime hazardous chemical accidents, the marine engineering professional knowledge service system and the construction of the national marine science data center , etc.**

Contents

1. Introduction

- In 2022, maritime trade accounted for 85% of global trade volume and is the main mode of transportation in global trade.
- The international sea freight volume of dangerous goods accounts for approximately 50% of the total sea freight volume.


- The transportation process of dangerous goods at sea is **complex, and there are many factors that affect their safety, with strong contingency and randomness**. Therefore, the marine environmental hazards generated after leakage are more difficult to predict.


- This article mainly incorporates data from Automatic Identification System(AIS), ships, and marine functional zoning into the environmental risk assessment index system for the movement of dangerous goods at sea. The Analytic Hierarchy Process(AHP) is used to establish a risk assessment model and **predict the impact of dangerous goods transportation ships on the adjacent marine environment**.

2. Data analysis

AIS data

Static information	Dynamic information	Voyage information
Maritime Mobile Service Identification	Ship position with longitude and latitude markings and integrity status	Planned route (turning point)
Call sign and ship name	Coordinated Universal Time(UTC) location timestamp	Destination
International Maritime Organization (IMO) number	Course over ground	Estimated time of arrival
Captain and width	Ground navigation	Dangerous goods (types)
Ship type	Heading	Ship draft
Global Positioning System(GPS) antenna position	Navigational status	Number of people on board
Ship height	Steering rate	

Ship archives

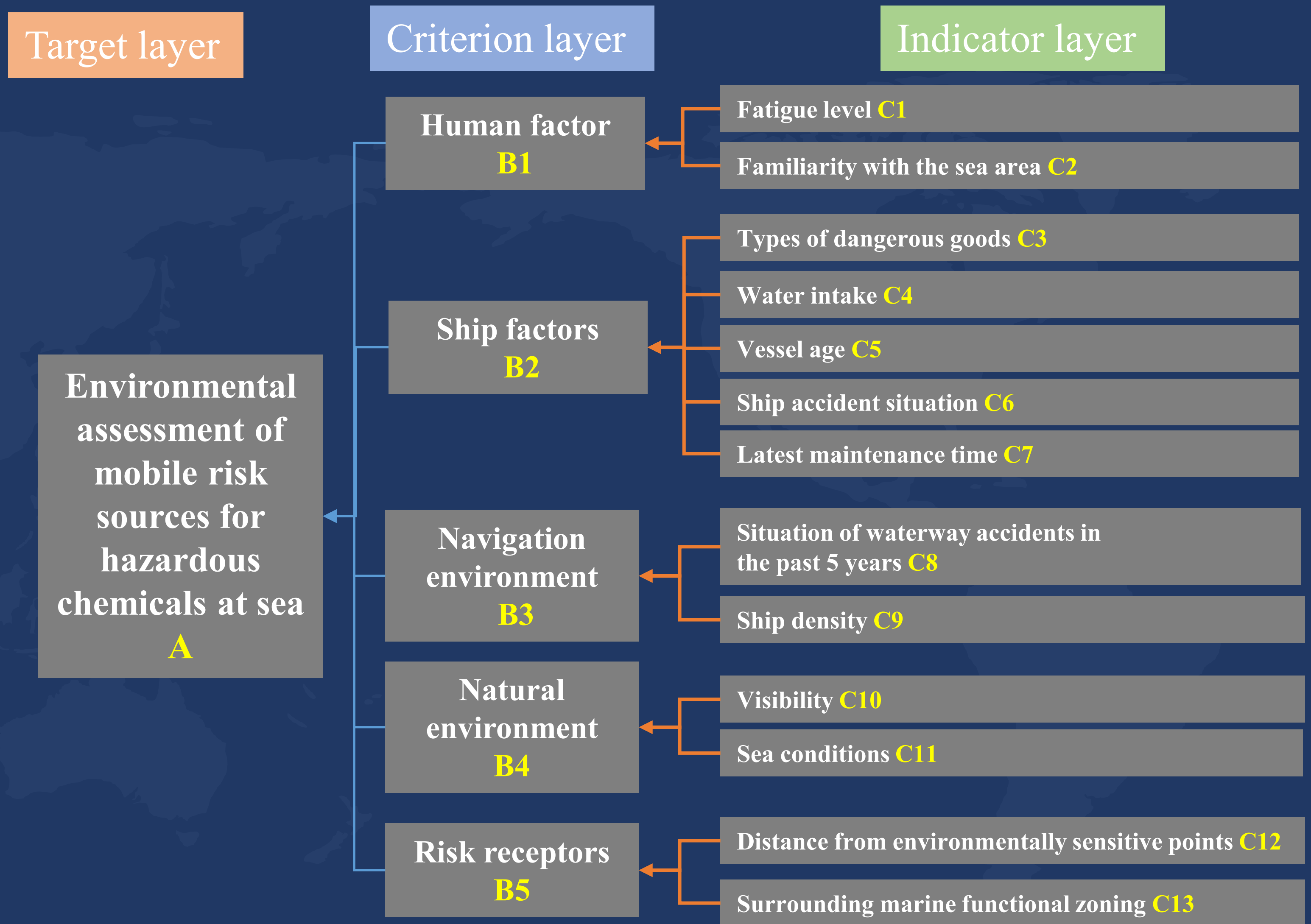
Ship information	Company Information	Shipyard Information	Accident Information
Registration Information	Corporate name	Contact information	Occurrence time
Affiliated company	Address	Contacts	Accident location
Vessel tonnage	Contact information	Address	Accident type
Various equipment parameters	organization structure	Delivery Date	Severity
Maintenance records	Fleet size		Casualty situation

✓ Dangerous goods transport vessel: Based on the types of dangerous goods in AIS data, the vessel and cargo hazard level for transporting dangerous goods can be accurately identified. Combined with ship archive data, information such as vessel age, whether accidents have occurred, recent repair time, and company name can be obtained.

✓ Real time ship location: Based on the longitude and latitude data of ships in AIS data, the channel information and ship density can be further calculated. Combined with ocean functional zoning data, the sea use information of the ship's location can be determined.

3. Composition of index system

- Taking into account the safety process and related safety factors in the transportation of dangerous goods at sea, this article uses **AHP** to set the hierarchical structure of the evaluation index system as the target layer, criterion layer, and indicator layer.
- **The target layer** is to construct an environmental indicator evaluation system for the mobile risk sources of dangerous goods at sea.
- **The criterion layer** considers five aspects: human factors, ship factors, navigation environment, natural environment, and risk receptors.
- **The indicator layer** is further refined into **13 indicators** . For ease of calculation, each indicator is divided into 3 levels.



Environmental indicator evaluation system for mobile risk sources of dangerous goods at sea

3. Composition of index system

- ✓**C1 Fatigue level:** ship travel time ≥ 15 days, 5-10 days, and<5 days. The longer the driving time, the easier it is for the crew to fatigue, and the ability to handle ship emergencies will decrease.
- ✓**C2 Familiarity with the sea area:** unfamiliar, uncertain, and relatively familiar. Using AIS location and IMO number to determine if crew members are familiar with the navigation area.
- ✓**C3 Types of dangerous goods:** major hazards, potential hazards, and minor hazards.
- ✓**C4 Water intake:** ≥ 10m, 5-10m, and<5m.
- ✓**C5 Vessel age:** ≥ 10 years, 5-10 years,<5 years.
- ✓**C6 Ship accident situation:** statistics of accidents occurring ≥ 3 times, 1-3 times,<1 time. Statistical analysis of ship accidents can reflect the overall risk and control status of the ship
- ✓**C7 Latest maintenance time:** maintenance time ≥ 3 years, 1-3 years,<1 year. The closer the maintenance time is, the more stable the equipment is, and the less likely it is to trigger safety incidents.
- ✓**C8 Situation of waterway accidents in the past 5 years:** major accidents, general accidents, and no accidents.
- ✓**C9 Ship density:** number of nearby vessels ≥ 5, 3-5,<3.
- ✓**C10 Visibility:** visible distance<1km, 2-5km, ≥ 5km.
- ✓**C11 Sea conditions:**. wind power level ≥ 10, 6-10,<6.
- ✓**C12 Distance from environmentally sensitive points:** calculate the distance between the vessel and the surrounding sea area functional zoning, divided into distances of<5km, 5-10km, and ≥ 10km.
- ✓**C13 Surrounding Marine Functional Zoning:** classification of sensitive, sub sensitive, and non sensitive areas in marine ecological environment.

4. Construction of Environmental Risk Assessment Model

Calculation of judgment matrix for mobile risk source analysis and evaluation model

Based on the established environmental risk assessment index system for mobile hazardous materials at sea, an expert scoring table is designed using a 1 ~ 9 scale method.

- ✓ The research fields involved marine chemistry, environmental assessment, risk research, marine engineering, etc.
- ✓ The highest and lowest scores of each indicator were removed respectively, and the average score of each indicator was calculated and substituted into the AHP formulas.

Scale	Define	Illustrate
1	Equally important	Compared to two factors, they have the same importance
3	Slightly important	Factor i is slightly more important than factor j
5	Obviously important	Factor i is significantly more important than factor j
7	Strongly important	Factor i is more important than factor j
9	Absolute Importance	Factor i is absolutely more important than factor j
2,4,6,8	Intermediate value of adjacent judgments mentioned above	
$a_{ji} = 1/a_{ij}$	If the importance ratio of factor i to j is a_{ij}, then the importance ratio of factor j to i is $a_{ji} = 1/a_{ij}$	

Scale and Meaning of 1-9 Judgment Matrices

4. Construction of Environmental Risk Assessment Model

■ Risk Assessment Model Weight Calculation Results and Risks

- According to the results of the AHP, the weight of the types of **dangerous goods transported** by ships is 0.270, and the distance weight of **sensitive points in the marine environment** is 0.234, respectively ranking first and second in the comprehensive ranking of the indicator layer.
- Global weights are used for indicator sorting, weights used for actual model calculations.

Target layer	Criterion layer	Weight	Indicator layer	Weight	Global weight	Sort
Environmental assessment of mobile risk sources for hazardous chemicals at sea A	Human factor B1	0.048	Fatigue level C1	0.50	0.024	12
			Familiarity with the sea area C2	0.50	0.024	11
	Ship factors B2	0.456	Types of dangerous goods C3	0.59	0.270	1
			Water intake C4	0.06	0.028	10
			Vessel age C5	0.16	0.071	4
			Ship accident situation C6	0.08	0.038	8
			Latest maintenance time C7	0.11	0.049	6
	Navigation environment B3	0.069	Situation of waterway accidents in the past 5 years C8	0.14	0.010	13
			Ship density C9	0.86	0.059	5
	Natural environment B4	0.147	Visibility C10	0.20	0.029	9
			Sea conditions C11	0.80	0.117	3
	Risk receptors B5	0.280	Distance from environmentally sensitive points C12	0.83	0.234	2
			Surrounding marine functional zoning C13	0.17	0.047	7

Weights and Ranking of Risk Source Evaluation Indicators for Mobile Dangerous Goods at Sea

4. Construction of Environmental Risk Assessment Model

Risk level classification

According to the high, medium and low risk levels of the 13 risk elements in the indicator layer, the values are respectively assigned as 3 points, 2 points and 1 point. Combined with the specific weight of each risk element in Table Weights and Ranking of Risk Source Evaluation Indicators for Mobile Dangerous Goods at Sea, the final score of the marine mobile risk source can be calculated between 5 and 15 points. According to the principle of equal division, the following mobile risk source level standards are defined.

- ✓ **M** is risk level classification
- ✓ **5 and 15 points** is multiply the weights of all indicator layers by 1 or 3

Comprehensive risk value	**11.7<M=<15**	**8.4<M=<11.7**	**5<M=<8.4**
Risk level	High risk	Medium risk	Low risk

Classification of Risk Levels for Mobile Risk Sources of Dangerous Goods at Sea

5. Application of Environmental Risk Assessment Model

Data sources

- In order to test the applicability of the evaluation index system of mobile risk sources at sea, dangerous goods transport ships in the Hangzhou Bay area are selected as research cases to evaluate the level of mobile risk sources.
- Hangzhou Bay has the largest port in China, Shanghai Port and Ningbo Zhoushan Port, and is also one of the busiest ports in the world. Its annual cargo throughput exceeds 550 million tons, and there are various marine functional zones nearby. If there is a leakage of hazardous materials, it will cause serious harm to the marine environment and cause serious economic losses in the local area. It is urgent to effectively monitor and warn ships transporting hazardous materials.

✓ Various marine functional zones near the sea area, such as passenger terminals, container terminals, coastal wetlands, marine nature reserves, scenic tourist areas, residential areas, agricultural and fishery areas.

✓ The real-time AIS data is sourced from the East China Sea Navigation Support Center of the Ministry of Transport, updated every 15 minutes, and covers the Hangzhou Bay;

✓ The marine weather forecast data is sourced from the website of the China Meteorological Administration;

✓ The historical data of ship archives is sourced from the shipping Big data project of the National Marine Information Center.

5. Application of Environmental Risk Assessment Model

Instance application

Real time data analysis

Seven hazardous chemical transport ships were subjected to real-time calculation and classification, with 5 at low risk and 2 at medium risk.

Target layer	Indicator layer	Weight
Marine Mobile Risk Sources 8.84	Fatigue level C1	1
	Familiarity with the sea area C2	1
	Types of dangerous goods C3	2
	Water intake C4	1
	Vessel age C5	2
	Ship accident situation C6	1
	Latest maintenance time C7	1
	Situation of waterway accidents in the past 5 years C8	2
	Ship density C9	1
	Visibility C10	3
	Sea conditions C11	2
	Distance from environmentally sensitive points C12	3
	Surrounding marine functional zoning C13	2

Ship IMO Number 27933XX

Serial Nuber	Ship IMO	Value	Gradtion
1	14007XX	7.26	Low risk
2	27933XX	8.84	Medium risk
3	20972XX	8.36	Low risk
4	95469XX	8.23	Low risk
5	98441XX	8.25	Low risk
6	91007XX	7.85	Low risk
7	91874XX	8.68	Medium risk

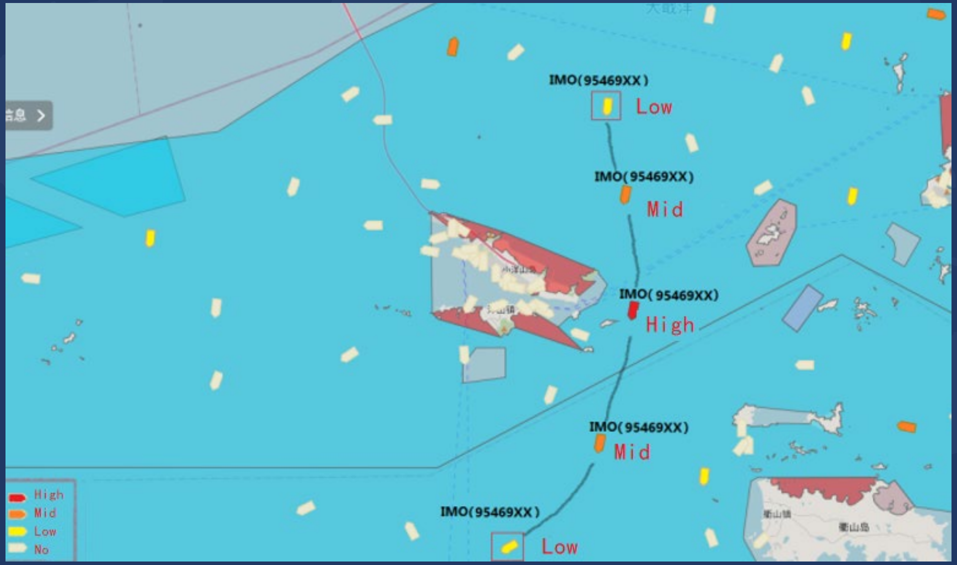
Classification of 7 Dangerous Goods Transport Ships at 9:00 pm

5. Application of Environmental Risk Assessment Model

■ Instance application

➢ Continuous data analysis

Dynamic risk level calculation is conducted for the movement trajectory of a hazardous chemical vessel, with a speed of 20 kilometers per hour and a 2-hour voyage. The vessel passes through marine ecological sub sensitive areas such as docks and scenic spots, and the risk level gradually changes from low to medium to high to medium to low.



Serial Nuber	Value	Gradtion
1	8.23	Low risk
2	9.19	Medium risk
3	11.74	High risk
4	9.22	Medium risk
5	8.33	Low risk

No.95469XX mobile risk source level from 9:00 to 11:00

6. Conclusion and future work

- The research results have been integrated and demonstrated in the emergency assistance system for maritime dangerous goods accidents, which can monitor ships in Hangzhou Bay area in real time, classify and warn dangerous goods transport ships, and provide reference for daily disaster prevention and reduction of marine environmental safety departments. For example, for high-risk ships, managers can timely understand the specific types of dangerous goods, notify nearby ships to avoid approaching, and on-site emergency monitoring personnel should be vigilant, etc.

- At present, classification level warnings have only been established for ships transporting dangerous goods at sea, and decision-makers usually pay more attention to regional risks. The next step is to use big data mining analysis technology, combined with other parameters such as destination port, estimated arrival time, and ship speed in AIS data, to predict the route and time of multiple dangerous goods transport ships passing through a certain sea area in advance, and establish regional risk level warnings, Timely optimize the layout of emergency monitoring personnel and materials in the jurisdictional waters.

Thank you!