Analysis of Maritime Traffic Safety Based on Intrinsic Safety Theory

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Abstract: Strengthening intrinsic safety of maritime traffic is essential for further modernization of the maritime traffic safety governance system and the governance capabilities. This paper studies the connotations of the intrinsic safety of maritime traffic, then analyzes the composition of the intrinsic safety system of maritime traffic and explores how to achieve intrinsic safety of the system factors such as crew, ships, navigation environment and safety management by referring to a typical case, and finally proposes maritime regulatory measures based on the intrinsic safety of maritime traffic and the long-term maritime management model for ensuring the intrinsic safety of maritime traffic.

1. Introduction
Maritime transport safety is increasingly important as the transport volume keeps rising. At present, the model built by linear regression method and exponential smoothing method is used to predict the potential transport volume.

The curve fitting expression is as follows:

\[ y = \sum_{j=0}^{m} a_j x^m = a_0 + a_1 x + a_2 x^2 + \cdots + a_m x^m, \quad (m \ll N) \]

N is the amount of sample. Generally, the amount is supposed to reach a certain degree, to ensure m is less than N.

Exponential smoothing model is as follows:

\[ F_{t+1} = A_i + B_i + \frac{1}{2} C_i T^2 \]

Through the use of both method, the outcome is more reasonable. The transport volume will increase significantly in the next decade, as much as 110 per cent. Simultaneously, as shown in the fig.1, the workload of search and rescue in China maintains at a high level in theses years.

| Year | 2015 | 2016 | 2017 |
|------|------|------|------|
| Search and Rescue (times) | 1884 | 2076 | 2063 |
| The action of Aircraft involved(times) | 318 | 306 | 360 |
| The action of ships involved(times) | 6619 | 10170 | 9390 |

If “Intrinsic safety” method is introduced to analyse the safety issues and assist to give advice, it will be a huge improvement in safety recognition and safety management. “Intrinsic safety” mainly refers
to the safety and reliability of people, objects, and systems in safety management, and “intrinsic” concerns the fundamental attributes of things that are inherent and determine their essence, appearance, and development. Intrinsic safety also represents humans’ change of attitude toward accidents in the practical processes of production and life, from passive reaction to proactive prevention, to eliminate accidents at the source.

2. Composition of the intrinsic safety system of maritime traffic
Maritime traffic is an intricate human-machine-environment system. The primary requirement for ensuring safe production with maritime traffic is the human-machine-environment system, i.e. the crew-ship-navigation environment system, should be intrinsically safe.

2.1 Intrinsic safety of the crew
The intrinsic safety of people has two basic meanings: First, intrinsically people want to be safe; and second, education, guidance and institutional constraints can enable people to achieve systematic safety and safety in their personal positions.

As a participant in maritime traffic, the crew is the most fundamental and crucial link of creating the intrinsic safety of maritime traffic. Fundamentally, the safety awareness and safety skills of the crew determine the incidence of accidents in ship navigation, berthing and operations.

2.1.1 Behavior characteristics and behavior patterns of the crew
As the pilot and operator of the ship, the skills, working state and safety awareness of the crew directly determine the safety of a ship during navigation. Since the crew is vital to the safety of ship navigation, it is of important and practical significance for improving the controllability of their behavior and enhancing the safety of ship navigation to effectively identify the crew factors.

2.1.2 Identification of safety risk factors of the crew
In the working environment, influenced by multiple factors such as physical condition, mental state, and the working condition, the behavior of the crew is sudden and unpredictable. The main related risk factors are as follows:

(1) Physiological factor
   This consists of the physical fitness and mental state of the crew. The mental state of the crew mainly refers to the fatigue level of the crew. [1]

(2) Psychological factor
   Psychological stability of the crew is important to the safety of ship navigation. Poor psychological health would be a great potential danger to navigation safety.

(3) Skills
   Ship navigation is a highly technical occupation. If the crew lacks the proper knowledge, basic skills and training, navigation safety inevitably cannot be guaranteed.

(4) Working attitude
   Safety awareness is a premise of the safety of ship navigation. Strengthening training of the safety awareness of the crew can prevent accidents caused by mishandling during emergencies.

2.2 Intrinsic safety of ships
Ships are the carrier of maritime traffic. They are the basic unit and the main executer of maritime traffic. The intrinsic safety of ships includes both the intrinsic safety of the hardware facilities like ship structures and equipment, and the intrinsic safety of the software such as daily ship management, navigation behavior, and emergency management.

2.2.1 Characteristics of ships and ship reliability analysis
Ships and ship equipment inevitably contain various dangerous and harmful factors which provide the physical condition for the occurrence of accidents. Only when ships and ship equipment are intrinsically
safe and highly reliable can accidents be prevented or reduced.

2.2.2 Identifying ship factors affecting safety

(1) Ship design and renovation
Once there is a quality problem in the design of a ship, the safety in using the ship in the later stage will be seriously affected. In addition, during ship renovation, the lack of a sound dynamic ship evaluation system can largely affect the performance of the renovated ship.

(2) Daily management
Strengthen the analysis of the performance and indicators of ships and ship equipment, establish a regular preventive maintenance system, and regularly inspect safety devices to ensure that they are consistently reliable and ready for use.

(3) Internal environment of ships
The environment of a ship includes its internal environment and its external environment. The internal environment of a ship refers to the spaces for onboard machinery and equipment and the hull and the working and living space of the crew, and the external environment of a ship is the external working and living conditions of the crew.

(4) Ship machinery and equipment
According to statistics, accidents caused by mechanical damage take up a significant part of all ship accidents. The poor working environment inside the ship has a great impact on the normal operation of ship machinery and the safe navigation of the ship.

2.3 Intrinsic safety of the navigation environment
The intrinsic safety of a navigation environment determines the navigation, berthing and operations safety of ships in this water area.

Navigation environment refers to the space and conditions in which the ship moves, including the navigational waters, natural conditions, and traffic conditions.

(1) Natural conditions
Visibility: The main hazard of poor visibility is that it reduces the distance of the sight. For one thing, it makes it difficult for ships to spot nearby aids to navigation and determine their positions. For another, it makes it impossible to keep a lookout. Furthermore, if the ship navigates and operates continuously with poor visibility for a long time, the psychological pressure on the crew would be huge. [2]

Wind, waves, and currents: Wind is an extremely irregular natural phenomenon. Ships tilt easily against wind, and will eventually capsize due to flooding. The changes in water depth and flow velocity caused by ocean currents and tides also have an impact on navigation safety, especially in the restricted waters near the shore or in the waters of the harbor and bay.

Rain, snow, and ice: Adverse weather conditions such as rain and snow lower visibility, and ice affects the navigation, anchoring and berthing of ships.

(2) Port conditions
Port waters include the water area for ships’ braking, berthing in front of the dock, turning, and anchoring. The conditions of port waters have a great impact on the safety of ships’ entering and leaving the port, mooring, and berthing.

(3) Channel conditions
They include the width, depth, bending angle, crossing, etc. of the channel. [3]

(4) Traffic
It mainly refers to traffic volume and traffic density, navigation aids, safe navigation speed and traffic management. [4]

(5) Engineering work on water and under water
Engineering work on water and under water affect the normal and safe entry and exit of the other ships. The technical conditions of construction ships are generally unfavorable and the ships are seriously old, with prominent hidden dangers to navigation and operations safety. [5]
2.4 Intrinsic safety of maritime traffic safety management
Maritime traffic safety management is composed of safety management of shipping companies and safety regulation of the maritime department. The shipping companies shall take the main responsibility for safety management and their safety management work shall be strengthened. That is, safety management of people, ships and environment should be incorporated into the daily safety management of the enterprise. At the same time, the maritime management department shall maintain supervision of people, ships, and environment as well as the safety management work of shipping companies. This model can effectively improve the maritime management department’s capabilities in governing maritime traffic safety and maximize the utilization of resources.

2.5 Mechanism of the intrinsic safety factors of maritime traffic
Fundamentally, intrinsic safety shows the focus of prevention of risks in production safety management. The intrinsic safety management of maritime traffic can be interpreted as an overall measurement of the direct factors of maritime traffic accidents, i.e. people, ships, and environment, by applying the ideas and methods from systematic engineering in the production activities with the ships. People are the core of the intrinsic safety of maritime traffic, ships are the foundation, environment the external conditions, and safety management the key factor.

3. Case analysis of a typical maritime traffic accident based on intrinsic safety
At about 8 p.m. on April 15, 2014, a South Korean RO-RO passenger ship, named the Sewol, departed from Incheon Port on its voyage to Jeju Island. At 7:58 a.m. on April 16, the ferry sent out a distress signal in the waters off Gwanmei Island, Jindo County, Jeollanam-do. Within two hours after the flooding began, the ship first rolled over, and then sank under the water. [6-7]

(1) Intrinsic safety analysis from the perspective of the crew
At the beginning of the accident, the crew failed to secure the vessel effectively with light-weight securing devices such as cables and nylon belts. As a result, the ship could easily move around longitudinally, laterally, and vertically, and even overturn, undermining the performance of the ship. At the same time, the artificial swerving of the ship during high-speed navigation might be the main cause of this maritime accident. The maneuvering of the ship at a large rudder angle caused the cargo to shift, changing the vessel’s center of gravity and eventually leading to the disaster of the ship’s rolling over and capsizing.

(2) Intrinsic safety analysis from the perspective of the ship
The Sewol had been reconstructed once, with the passenger capacity of the third, fourth, and fifth decks expanded. This raised the center of gravity of the vessel, greatly reduced its initial stability, and increased the probability of capsizing.

Rudder failure might be one of the causes of the accident. Since the rudder had been defective, it might have gone beyond the instruction of the pilot and continued to turn until the maximum rudder angle. Then the ship became uncontrollable, lost balance and overturned.

Besides, as a ro-ro passenger ship, the Sewol does not have sufficiently dense transverse and longitudinal bulkheads. Its resistance to sinking was seriously insufficient.

(3) Intrinsic safety analysis from the perspective of navigation environment
Another possible cause of the accident was that the ship hit the rocks. The waters of the shipwreck are frequently misty, where the terrain of the seabed is complex and changeable and scattered with many underwater obstructions against navigation.

(4) Intrinsic safety analysis from the perspective of safety management of shipping companies and safety regulation of the maritime department
At the occurrence of the accident, the Sewol had deviated from the navigation route recommended by the Ministry of Oceans and Fisheries of South Korea, which was also one of the important causes of the tragedy. The shipping company had not given enough skill training to the crew, which caused the crew’s lack of safety awareness. At the same time, the related regulation department had failed to put the ship under thorough supervision in their daily management.
4. Regulatory measures based on the intrinsic safety of maritime traffic

4.1 Measures for controlling the risk factors of the crew
As a participant in maritime traffic, the crew is the most fundamental and crucial link of creating the intrinsic safety of maritime traffic. The crew’s sense of obeying the laws and regulations and professional honor should be strengthened by induction training and assessment, ethics education, emergency coping skill training, etc. It is also necessary to continuously optimize the crew education and training system, emphasize problem-oriented training, and constantly push forward the innovation and optimization of crew training methods, content, and crew assessment.

4.2 Measures for controlling the risk factors of ships
Ships are the carrier of maritime traffic. They are the basic unit and the main executor of maritime traffic. The intrinsic safety of ships includes both the intrinsic safety of the hardware facilities like ship structures and equipment, and the intrinsic safety of the software such as daily ship management, navigation behavior, and emergency management.

4.3 Measures for controlling the risk factors of navigation environment
To keep navigation environment under control, we should implement source governance and enhance the control of the intrinsic safety of navigation environment to build an intrinsically safe environment. To create an intrinsically safe environment, for one thing, we should endeavor to collect and summarize data like the water depth and weather conditions of the navigation route, the functions, the traffic density, and the characteristics of ship crossings; for another, we should strengthen early warning and prevention against sudden and severe weather conditions, water level changes etc., to create a favorable navigation environment for ship operations. [8]

4.4 Measures for controlling the risk factors of shipping companies
First, it is necessary to strengthen the supervision and management of shipping companies, urging them to execute their main role in ensuring production safety; secondly, more efforts should be made to promote safety concepts within shipping companies; and thirdly, the inspection of the management of shipping companies involved in ship accidents should be strengthened.

5. Establishing a long-term maritime management model for ensuring the intrinsic safety of maritime traffic

(1) Comprehensive governance
Encourage governments with the jurisdiction to execute their responsibilities for directing production safety, by relying on local governments and relevant departments; explore incessantly how to establish a regular consultation system among departments and organizations of water conservancy, waterways, port and shipping, public security, ship inspection, transportation management, banking and insurance, strengthen information sharing and coordination, and achieve well-coordinated joint law enforcement and integrated law enforcement, so as to promote production safety of shipping companies.

(2) Prevention and pre-control
Strengthen risk management, further normalize and promote risk management at the grassroots level, establish a risk-oriented cruise patrolling supervision and management model, and speed up the construction of the risk prevention and control system and the governance system for potential danger investigation and elimination, to consistently coordinate safety regulation under the concept of risk prevention and pre-control.

(3) Focuses
Reinforce the effort to strictly review the qualifications of shipping companies, scrupulously register ships and carefully issue crew training certificates. Strengthen ship registration, do well in examining and approving dangerous cargoes entering and exiting the port, regulate ship inspection operations, and
cooperate with ship inspection agencies to establish the major ship defects notification and reporting system.

(4) Innovative development

For one thing, urge shipping companies to strengthen technology and information construction, help them constantly transform and upgrade themselves, and build the safety management system of modern dynamic supervision and early warning and prediction; for another, the maritime department should actively innovate safety supervision concepts and systems, push forward the construction of the maritime system of the list of rights and responsibilities, persist in the reform to flatten management structures and optimize and upgrade the electronic cruise patrolling system, so as to build a modern safety regulation model.

(5) Source management

Shipping companies should increase their investment in ensuring production safety, strengthen the effort to repair, maintain and upgrade ships, and guarantee that their ships are suitable for navigation. They should also strengthen crew building, provide further navigation and skill training for the crew, and enhance the crew’s sense of obeying the laws and regulations, to ensure that the crew is competent for their jobs.

(6) Implementation of safety responsibilities

Formulate solid safety measures according to the requirements of laws and regulations, reinforce the implementation of safety responsibilities at all levels, improve production safety management capabilities, and adopt scientific decision-making.

(7) Social supervision

Encourage public engagement in safety work, spread safety know-how, improve people’s awareness and knowledge of safety, promote the safety culture, and allow news media, online newspapers, WeChat and Weibo, etc. to play a role in public opinion supervision. Cultivate the safety culture and carry out activities such as promoting relevant laws and regulations, providing training on maritime traffic safety, and delivering themed presentations. [9]

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