American Journal of Traffic and Transportation Engineering
2024, Vol. 9, No. 3, pp. 54-62
https://doi.org/10.11648/j.ajtte.20240903.12

Research Article

Research on Risks and Countermeasures of Berthing and Unberthing in Luojing Container Terminal

Yingqun Mei[1], Bin Cai[1], Binbin Zhou[1], Jie Wang[2,*]

[1]Shanghai Maritime Pilots' Association, Shanghai, China

[2]Merchant Marine College, Shanghai Maritime University, Shanghai, China

Abstract

In order to further enhance the container throughput capacity of Shanghai Port, a total renovation of the terminal at Luojing port area is planned. The successful implementation of the renovation project not only needs to fully consider the updating of technology and facilities, but also requires an in-depth analysis and assessment of the risks of berthing and unberthing container ships. In this paper, we will collect and organize the hydrometeorological conditions around the terminal, as well as the existing conditions of the port area and the waterway. Through in-depth analysis of the traffic flow data of Luojing Container Terminal, this research will study the navigational environment in the vicinity of the terminal and explore the characteristics and changing trends of the traffic flow. These analyses will help to accurately assess the impact of traffic flow on the safety of berthing and unberthing of container ships. Eventually, this paper will combine the results of the traffic flow analysis of Luojing Container Terminal to propose corresponding risk assessment and response strategies for berthing and unberthing. These strategies will provide a scientific basis for the terminal management to make future decisions, ensure the smooth progress of the renovation project, and enhance the transportation efficiency and safety of the Shanghai port.

Keywords

Luojing Container Terminal, Traffic Flow, Ship Flow, Berthing and Unberthing Risks

1. Introduction

As one of the main coal transportation terminals of Shanghai Port, Luojing Coal Terminal is facing the challenges of decreasing demand for coal transportation and increasing environmental protection requirements. In order to meet the market demand and promote the sustainable development of Shanghai Port, it is necessary to transform and upgrade Luojing Coal Terminal into a container terminal. However, with the increase in the number of container ships berthing, the risk of berthing and leaving and the difficulty of traffic organization in Luojing container terminal will increase dramatically.

Many scholars have carried out relevant studies on berthing and unberthing risks and traffic organization, for example, Li Changhui has made a simple analysis of the navigational risks and traffic organization of LNG vessels entering and leaving the Binhai port area [1], Yu Songrong analyzed and studied the risk of berthing container ships in the port area, and summarized the safer berthing and unberthing routes by simulating and analyzing the ship sailing process [2], Mengxia Li et al. proposed a grid-based collision risk identi-

*Corresponding author: wangjie1@shmtu.edu.cn (Jie Wang)

Received: 1 July 2024; **Accepted:** 23 July 2024; **Published:** 6 August 2024

fication and prediction model in order to facilitate real-time collision risk analysis of busy ports and waterways, combining historical accident data and marine traffic data [3], Ashim Kumar Debnath et al. have developed a set of risk prediction modeling techniques that can be effectively used for channel collision risk prediction, and in order to assess the safety of a channel after a change in its characteristics, the model can also be effectively used to predict channel collision risk [4], Giulia Marroni et al. developed a specific risk-based analysis matrix methodology to support the identification and assessment of potential accidents associated with LNG carriers transiting through risky staging in port areas, providing indications for risk control in terms of prevention and mitigation measures [5].

Although a lot of researches have been done by the predecessors, it is still worthwhile to study the operation area of Luojing Coal Terminal which is adjacent to Baoshan South Fairway, and there are other major fairways nearby, such as Baoshan North Fairway, Baoshan Fairway, Baoshan Branch Fairway, Xinqiao Passage, Xinqiao Waterway and other major fairways, and the traffic flow is relatively busy, and the risks of berthing and unberthing are relatively large. In this paper, the research studies the traffic flow in the nearby waters of Luojing operation area, derives the risks of berthing and unberthing, and puts forward a reasonable traffic organization and arrangement scheme, to provide a decision-making basis and suggestions for the safe operation of the terminal, and to improve the competitiveness of the terminal and its market position.

2. Current Status of the Terminal at Luojing Container Terminal

2.1. Hydro Meteorological Profile and Impacts

Wind conditions: The prevailing winds in Shanghai Harbor are northerly in winter and southerly in summer, with obvious seasonal changes. During the year, the average wind speed is the highest in March-April in spring, followed by January-February in winter and summer, and the lowest in September-October in fall. According to the meteorological statistics of Baoshan Meteorological Station in the past three years (2020-2022), the prevailing winds are in the directions of ESE and NNE, and the maximum wind speed reaches 23.1m/s, mostly in the directions of NE and ENE, and the average wind speed is 4.7m/s. The average wind speed is 4.7m/s, and the average wind speed is 4.7m/s.

The direction and speed of the wind have a direct effect on the maneuvering and heading stability of a ship [6]. When a vessel is approaching or leaving a terminal, the direction and speed of the wind can create thrust or resistance to the direction and speed of the vessel's travel. Strong winds may cause a vessel to deviate from its intended course, increasing the risk of collision with other vessels or terminals. In certain geographic areas, wind-slow zones or wind-urgent zones may be formed due to factors such as topography or buildings. A wind slow zone is an area where the wind speed is low, while a wind fast zone is an area where the wind speed is high. Vessels may experience sudden changes in wind speed when entering or leaving these areas, increasing operational uncertainty and risk.

Tides: According to the measured tide data from the tide station to draw the curve of tidal process (Figure 1), the tidal change near Luojing has a fairly consistent and obvious pattern; in the change of one day of taiyin, there are two high tides and two low tides regularly, presenting obvious semi-diurnal tidal characteristics; at the same time, the phenomenon of "unequal days" of the tides is more obvious, and there are both unequal adjacent tide differences and unequal rise and fall time in one day of taiyin. At the same time, the phenomenon of "unequal days" of tides is more obvious, a taiyin day has both unequal neighboring tides and unequal rise and fall times, and there are both high and low tides in the high and low tide levels, and there are both high and low tides, and there is an obvious "unequal high tides" and "unequal low tides" phenomenon.

Tidal-induced changes in water levels can lead to changes in the depth of water in a harbor or body of water. Water depth is a critical factor in berthing and unberthing operations, especially for large ships [7]. If a ship leaves a harbor with insufficient water depth, it may run aground or collide with an undersea obstruction. Similarly, if a vessel is not deep enough when berthing, it may not be able to get close enough to or flush with the quay, increasing the risk of collision. Tides also bring about changes in water currents, including tidal currents and up and down currents. The speed and direction of these currents have a significant impact on a ship's berthing and unberthing operations [8]. When the speed of the currents is high, vessels need to make corresponding adjustments when berthing or departing to overcome the effects of the currents and to avoid deviation from the channel or collision.

Waves can have an impact on the stability of ships. Large waves may cause ships to be subjected to violent rocking during berthing and unberthing operations, increasing the risk of collision with other ships or terminals. Particularly during berthing, wave-induced ship rocking may make the ship's contact with the quay unstable, increasing operational difficulties. Wave-induced ship rocking and course changes may increase the difficulty of ship maneuvering. Particularly in narrow harbors or waterways, waves may make the maneuvering of a vessel more complicated and require greater skill and experience. Maneuvering difficulties increase the risk of collision with other ships or terminals.

Ships are mainly affected by wind and current during berthing and unberthing, and the relevant calculation formulas are as follows:

$$F_{wi}(t) = \frac{1}{2} C_{wi} \rho_{ai} A_{wi} v^2{}_{wi} \quad (1)$$

$$F_{cu}(t) = \frac{1}{2} C_{cu} \rho_{wa} A_{cu} v^2{}_{cu} \quad (2)$$

Where C_{wi} and C_{cu} are the wind and flow coefficients, ρ_{ai} and ρ_{wa} are the densities of air and seawater, A_{wi} and A_{cu} are the windward and flow areas of the platform, v_{wi} and v_{cu} are the wind and flow velocities, respectively, and F_{wi} and F_{cu} are the wind and flow forces, respectively, and the above units are in the International System of Units [9].

2.2. Channel Layout

Luojing container terminal is adjacent to Baoshan South Channel, and other nearby channels mainly include Baoshan North Channel, Baoshan Channel, Baoshan Branch Channel, Xinqiao Passage, Xinqiao Waterway, etc. The distribution of the nearby channels of Luojing container terminal is shown in Figure 1.

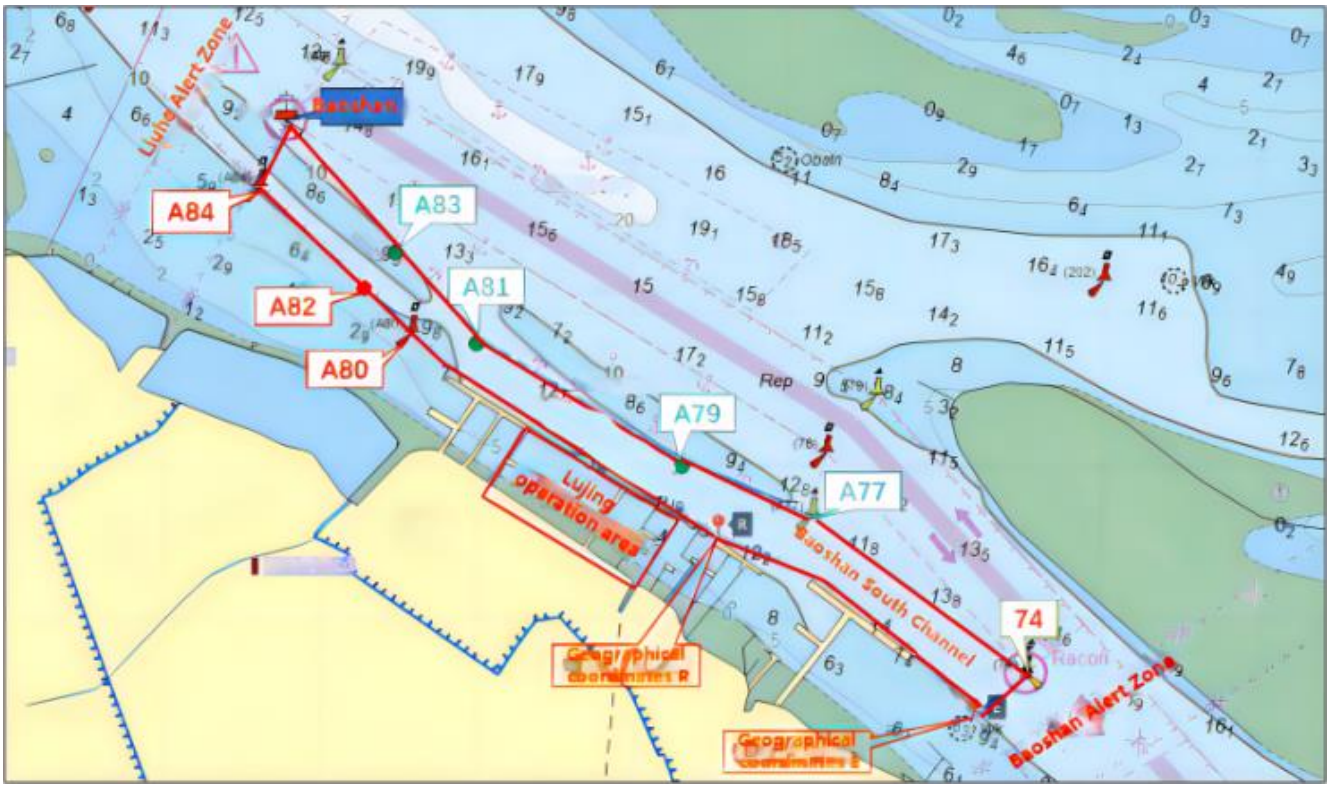

Figure 1. *Schematic distribution of waterways near Luojing container terminal.*

Baoshan Channel: Baoshan Channel is connected to Baoshan Alert Area on the top and Wusongkou Alert Area on the bottom, it is a compound channel, which consists of 67, 69, 71, 73 right side marker light floats and 66, 68, 70, 72 left side marker light floats. The middle 460m of the channel is the extension of the deep water channel in the mouth of the Yangtze River, and virtual markers are set up on the side line; the two sides are the small boat channel, and physical markers are set up on the side line, and the width of the markers is around 1,000m, and the length of the channel is about 4 nautical miles, and the natural depth of the channel is basically more than 12.5m (theoretical low tide surface). Baoshan Channel is also the main channel of the Shanghai section of the Yangtze River estuary, and the channel dividing line is the dividing line of the import and export navigational channel for large ships to enter and exit the Yangtze River.

Baoshan South Channel: It is clearly stipulated in the Provisions on Ship Routing System of Shanghai Section of Yangtze River that Baoshan South Channel is from the west boundary of Baoshan Alert Area to the east boundary of Liuhekou Alert Area (the line of Baoshan Light Float/A88 Light Float), and its north boundary line is the line connecting the light floats of No. 74, No. A77, No. A79, No. A81, No. A83 and Baoshan Light Float in turn. The southern boundary line is: geographic coordinates E (31°27′40.5″N / 121°26′38.1″E), along the northern parallel line 100 meters from the front of Baosteel's main raw material wharf, through the geographic coordinates R (31°28′59.8″N / 121°24′32.5″E), to the northern parallel line 100 meters from the front of Luojing wharf, connecting A80, A82 and A84. Lightships. The total length of the channel is 6.7 nautical miles, width is 450m~700m, water depth is more than 10.4m, which is used for the navigation of large ships exporting and ships entering and exiting from the south coastal wharf.

Baoshan North Channel: from the western boundary of Baoshan Alert Area (74 lamp floats) to the eastern boundary

of Liuhekou Alert Area (Baoshan lamp floats), the total length of the channel is 6.7 nautical miles, with a width of 1,000 meters, and in the middle of which 350m-460m is the extension of the deep-water channel of the Yangtze River estuary, and the maintenance depth of the deep-water channel is 12.5m (theoretical low tide surface). The channel dividing line is used as the dividing line between the import and export navigation channels for large ships to enter and exit the Yangtze River.

Baoshan Branch Channel: Baoshan Branch Channel is located in the south side of Baoshan waterway, except for the international cruise port, the ship maintenance bottom elevation-10.8m, the rest of the navigation section with natural water depth, the channel width is about 400~900m, the natural water depth of the channel is 8~10m. According to the Ministry of Transportation and Communications in December 2017 issued the "Regulations on Ship Routing System of Shanghai Section of the Yangtze River," the channel is mainly for the navigation of small ships, but also is the approach channel for coastal terminals. The channel is mainly for small vessels and is also the approach channel for coastal jetties. "The natural water depth of this channel can better meet the navigational requirements of small vessels, which refer to vessels under 3,000 gross tons, with full load draft not exceeding 7.4m.

3. Traffic Flow Analysis of Luojing Container Terminal

3.1. Complex Navigational Environment in the Vicinity of Luojing Terminal

In the narrow waterways of the Luojing container terminal, vessels usually encounter a large number of other vessels, resulting in a dense traffic flow. This increases the risk of mutual interference and collision between vessels. Vessel operators need to be alert at all times, closely observe the dynamics of surrounding vessels and take appropriate avoidance measures to avoid collision with other vessels. Adverse weather conditions around the Luojing container terminal such as high winds, dense fog and strong waves will also increase the navigational risks. These weather conditions reduce visibility, make vessel operations more difficult and increase the risk of collision with other vessels. Under these conditions, ship operators need to rely on auxiliary means such as radar, communication equipment and navigation tools to ensure the safe navigation of the ship. Human error in judgment is a common risk in complex navigational environments. Factors such as lack of experience, fatigue, and distraction may lead to errors in judgment, increasing the risk of collision [10].

With the growth of international trade and the advancement of globalization, the number of ships in the Luojing container terminal has been increasing. Various types of ships, such as large container ships, bulk carriers, tankers, etc., are flooding into Luojing container terminal, which leads to the increase of ship traffic flow in Luojing container terminal. Different types of ships have different navigation characteristics and maneuvering needs. In Luojing container terminal, there are not only large cargo ships, but also ferries, yachts, fishing boats and other ships of various sizes and purposes. These different types of vessels may need to use different strategies and procedures in berthing and unberthing operations, increasing the complexity of the traffic flow in the Luojing container terminal [11].

3.2. Traffic Flow Statistics and Summaries

In order to fully analyze the ship navigation flow situation in Luojing container terminal section, through the AIS application system, 10 ship flow statistical sections were set up in the upstream and downstream Baoshan North Channel along the outer edge of the terminal of Luojing container terminal in Baoshan South Channel, No. 81 Float, No. A79 Float, No. A81 Float, Baoshan Alert Area, Chongming Branch Channel, Liuhekou Alert Area, Luojing Terminal North Front, Luojing Terminal Mouth, Luojing Terminal South Front, Shidongkou Ferry, and the ship navigational trajectory line statistical area was set up, and the ship types of the statistical data included all the vessels that passed by the observational sections and the statistical area, such as the cargo ship, the passenger ship, the dangerous goods vessel, the fishing ship, the engineering ship, and the working ship.

The statistical period is from January 1, 2021 to December 31, 2021. According to the observed ship flow data, the statistics of ship flow observation in the statistical section of the proposed terminal area, the total ship flow of each observation line is shown in Figure 2, and the amount of ship AIS data in each month of 2021 is shown in Figure 3.

The data in Figure 2 shows that the annual traffic in the Treasure Hill Caution Area far exceeds that of other areas, reaching 378,348 events. This peak in activity may be related to the area's heavy shipping traffic, important economic status, or geographic advantage as a major shipping hub. In contrast, the Liuhekou Caution Area had the next highest annual activity of 269,092, which may reflect the geographic or economic importance of the area, but not as much as the Baoshan Caution Area.

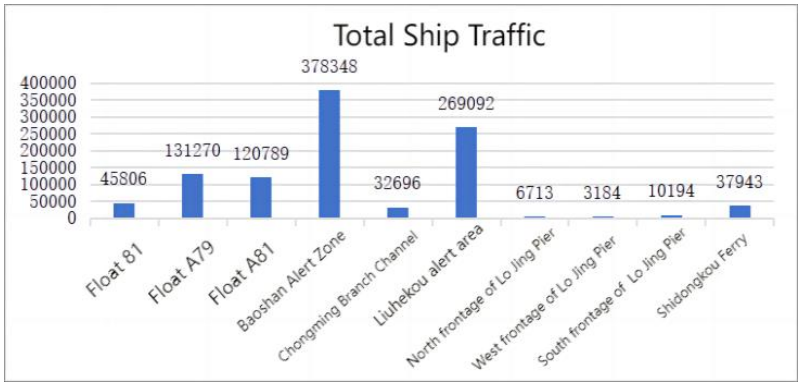

Figure 2. *Total ship traffic by observation line.*

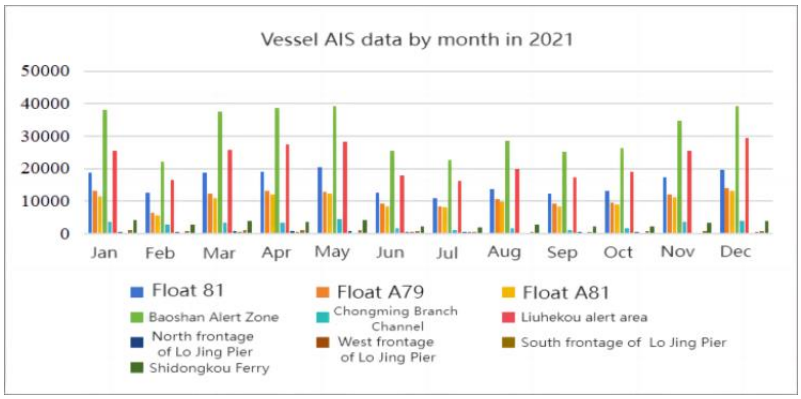

Figure 3. *Vessel AIS data volume by month in 2021.*

Looking at the monthly data in Figure 3, it can be seen that all districts experienced fluctuations in AIS activity volume over the course of the year. The significant rise in activity in the Baoshan alert area in January, March, April, May, and December may be associated with increased seasonal trade activity, such as the transportation of goods prior to the holiday season. In contrast, the peaks in activity in the Liuhekou alert area area in April, May, and December may be associated with specific regional events or economic activities, such as seasonal shipments of agricultural products or cyclical exports of industrial products.

The lower activity in the other areas in comparison suggests that they may be playing a lesser role in the shipping network. The lower activity in these areas may be due to naturally lower shipping volumes, or may be due to their lower shipping flows compared to the Treasure Hill Caution Area and the Liuhekou Caution Area.

According to the ship traffic statistics of Luojing container terminal, this study can observe that the ship traffic in this operation area is large. This situation not only increases the difficulty for the pilot of the ship itself, but also undoubtedly increases the probability of collision. This also increases the workload and difficulty for the relevant departments of maritime management accordingly. Through the analysis of various ship data, this study can clearly see the impact of traffic flow on ship driving and traffic organization.

4. Risks of Berthing and Unberthing at Luojing Container Terminal

The risk of berthing and unberthing should be considered as the primary aspect by both ports and supervisory departments as well as ships, and much research has been done on the risk of berthing and unberthing. Tao Xuebing analyzed the tidal currents and meteorological conditions of Yongzhou dock and proposed that the pilotage plan should be done well, the ship's speed and position should be research controlled as early as possible, the tugs should be brought in early and the contingency plan should be done well, and the good boating skills should be fully utilized to ensure the safety [12]. Chen Donghua emphasized that during berthing and unberthing, all staff of the ship should cooperate with each other under the command of the captain and do a good job of berthing and unberthing safely [13]. Wang Zijian proposed that the crew, pilot, tugs and other parties should do a good job of communication and preparation, reasonable control of berthing speed and angle, reasonable arrangement of tugs, and good cooperation with tugs [14]. These listed parts of the study have prepared for the next step of risk analysis of berthing and unberthing at Luojing Container Terminal.

4.1. Berthing and Unberthing Risk Analysis and Summary

During berthing and unberthing of vessels, the high traffic flow in the Luojing container terminal increases the operational difficulty and potentially raises the risk of accidents. The following is a comprehensive analysis of berthing and unberthing risks based on the issues raised in the previous three chapters:

Risk of collision: The high annual activity in the Luojing container terminal indicates that a large number of vessels regularly enter and leave the area. This increases the risk of collisions between vessels, especially in low visibility (e.g. foggy days) or night conditions. The high frequency of activity may also lead to crew fatigue, further increasing the likelihood of mishandling.

Risk of grounding and reefing: Due to the large number of ships, changes in water levels caused by high and low tides can lead to changes in the depth of water in harbors or waters, and some ships may be forced to deviate from the regular shipping lanes in order to avoid collisions, which may lead to grounding or reefing, especially for ships that are unfamiliar with the hydro geology of the area.

Traffic congestion: The monthly activity charts show particularly high activity in some months, which can lead to traffic congestion, which can prolong waiting times for vessels and increase the risk of accidents due to long waits or rushes to berth or leave.

Environmental factors: Meteorological conditions within the Luojing container terminal, such as strong winds, changes in current speed, and sudden bad weather (e.g., thunderstorms or typhoons), may affect the safety of ship maneuvering, especially for large ships or ships carrying dangerous goods.

Channel characteristics and hydro graphic conditions: Water depths, currents and tidal variations in the area are all factors that need to be taken into account during berthing and disembarkation. These conditions may add to the complexity of berthing and unberthing during periods of high tidal variability or special hydro graphic events.

Human factors: These include crew fatigue, inexperience, and disorganized communications due to too many ships, all of which can cause berthing and unberthing accidents in a dense flow of ships.

Taking these risk factors together, it is recommended that a series of risk mitigation measures should be adopted in Luojing District, including but not limited to strengthening the regulation of waterways, enhancing the capacity of navigation facilities, optimizing the traffic organization and vessel scheduling, and enhancing the training and awareness of crew members. These measures can significantly reduce berthing and unberthing accidents caused by high traffic flow and other risk factors.

Therefore, it is crucial for the Luojing container terminal to understand and analyze the impact of vessel traffic on vessel steering and traffic organization. This helps to develop more effective management strategies and safety measures to ensure safe and smooth vessel operations.

4.2. Fish Bone Diagram Risk Analysis Method

Fish bone diagram method is a risk analysis method to see the essence through the phenomenon, the use of fish bone diagram method to analyze the cause of the accident through reverse thinking, clear and logical, can systematically and effectively organize the relationship between the factors of the accident, such as Figure 4 [15].

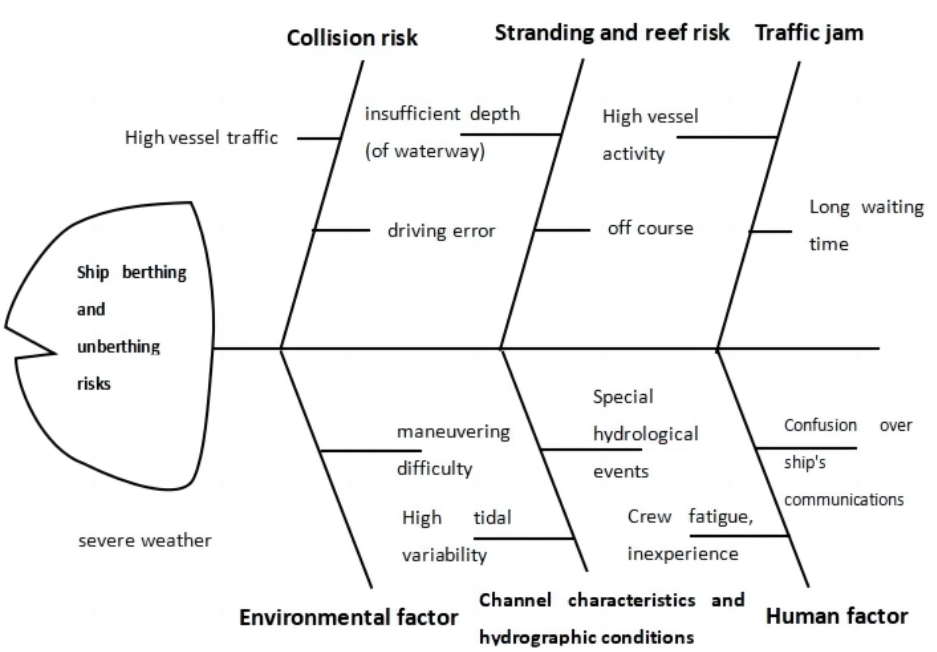

Figure 4. Fish bone diagram of ship berthing and unberthing risks.

These factors are often interrelated and together affect the safe navigation of ships. Therefore, the pilot of a ship needs to take these factors into account and take appropriate preventive measures to avoid collisions.

5. Traffic Organization and Management

Under the new trend of development of green, low-carbon, and intelligent shipping industry, the large-scale, intelligent, and specialized ships, gradually increasing ship traffic flow, and complex navigable water environment have put forward higher requirements for the management of shipping industry traffic organization. How to organize water traffic to ensure navigation safety, improve How to organize water traffic to ensure navigation safety, and improve the efficiency of ship traffic has gradually become one of the core issues in the field of traffic management research [16]. In order to improve the efficiency of ship navigation in ports, Liu et al. proposed a ship traffic organization method with full voyage constraints considering the characteristics of irregular ship speeds, and the validation shows that the established model has a small relative error, is highly generalized, and can effectively improve the efficiency of ship traffic organization [17].

5.1. Definition of Traffic Organization Management

The berthing and unberthing operations of ships are key aspects that must be emphasized and effectively managed by every port and terminal management. Risks during berthing and unberthing not only affect the ship's own safety, but also may cause damage to port facilities and the surrounding environment. Therefore, ship traffic organization management plays a crucial role in berthing and unberthing risk management.

Effective risk management of berthing and unberthing requires comprehensive consideration of several factors. The first is environmental factors, such as weather conditions and sea state, which directly affect the safety and feasibility of ship operation. Secondly, it is the ship's own characteristics and loading situation. Different types and sizes of ships have different operational needs when berthing and unberthing, and managers need to formulate corresponding operational procedures and guidelines according to the actual situation.

5.2. Traffic Organization Management Improvement Measures

In order to reduce the risk of ships berthing and departing [18], the following improvements can be made to traffic organization and management:

Strengthening ship traffic management: Establish effective ship traffic management systems, including navigation rules, signaling systems and communication equipment. These systems can provide real-time ship position information, help ships avoid collisions and ensure that ships berth and leave safely.

Provision of accurate waterway and harbor information: Ensure that navigational charts, bathymetric data and other relevant information on waterways and harbors are accurate and up-to-date. Ships can rely on this information to avoid potentially dangerous areas and obstacles.

Enhanced ship communication capabilities: Improve communication capabilities between ships and between ships and port authorities. Good communication capabilities can help ships to make better decisions in high-traffic areas and to get timely warnings of emergencies.

Enhance training and certification of ship's pilots [19]: Ensure that ship's pilots are fully trained, familiar with the rules of the road and operating procedures, and have good seamanship skills. In addition, establish an effective certification system for pilots to ensure that only qualified personnel can serve as ship pilots.

Implementing traffic control measures: Setting up traffic control areas in waterways and ports to limit the speed and density of ships and reduce traffic congestion and confusion [20]. This can be accomplished by setting up channel markers, guiding ship navigation, and limiting the number of ships.

Provision of good port facilities: Improve port infrastructure and facilities such as berthing bridges, moorings, lighting and signage. This can provide better berthing conditions for ships and reduce the risk of berthing and unberthing.

Conducting accident investigations and learning: Ship collision accidents that occur are thoroughly investigated and lessons are learned from them. By analyzing the causes and processes of accidents, improvement measures can be identified and applied to avoid the recurrence of similar accidents.

The above are some recommendations and measures to improve the risk of berthing and unberthing of ships. The combined application of these measures can improve navigational safety and minimize the occurrence of accidents.

6. Conclusions

This paper focuses on the berthing and unberthing risks and traffic organization problems in Shanghai Luoging container terminal, and puts forward a series of targeted improvement measures and management suggestions through meticulous data collection and analysis. At the initial stage of the study, the basic framework of the study was established through a comprehensive research on the hydro-meteorological conditions, channel layout and anchorage settings of the Luojing container terminal and its neighboring

waters. These basic data not only provide the necessary preconditions for risk assessment, but also lay a solid foundation for the development of traffic organization strategies. Utilizing modern technical means such as AIS application system, this paper carries out accurate statistics and dynamic monitoring of vessel traffic in Luojing container terminal and its surrounding waterways.

By comparing and analyzing the changes of vessel traffic in different time periods, it reveals the characteristics and trends of the traffic flow in Luojing container terminal, and provides detailed data support for the subsequent risk assessment and traffic organization. This study not only focuses on the influence of vessel traffic on berthing and unberthing risk, but also explores the influence of meteorological conditions, channel characteristics, human factors and other aspects on the safety of berthing and unberthing. The risk of berthing and unberthing in Luojing container terminal is comprehensively analyzed by constructing a fish bone diagram risk assessment model, which provides a scientific basis for the formulation of targeted risk mitigation measures. Based on the in-depth analysis of berthing and unberthing risks in Luojing container terminal, a series of traffic organization schemes are proposed in this paper. These schemes aim to effectively reduce berthing and unberthing risks and improve terminal operation efficiency by optimizing ship scheduling, improving channel utilization efficiency, and enhancing ship communication and information sharing.

In summary, through comprehensive and in-depth analysis and research, this study puts forward a series of scientific and reasonable suggestions and solutions for the risk management and traffic organization of berthing and unberthing in Luojing container terminal, which is of great theoretical value and practical significance for improving the safety operation level and management efficiency of Luojing container terminal and similar ports and terminals.

Abbreviations

LNG	Liquefied Natural Gas

Author Contributions

Yingqun Mei: Writing – original draft, Writing – review & editing

Bin Cai: Data curation, Methodology

Binbin Zhou: Formal Analysis, Validation

Jie Wang: Resources, Supervision

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Changhui Li. (2023). Study on Navigation Risk and Traffic Organization for LNG Ships Entering and Leaving Binhai Port Area. Pearl River Water Transport, (17), 41-43. https://doi.org/10.14125/j.cnki.zjsy.2023.17.022

[2] Songrong Yu, Feng Zhu. (2022). Risk Assessment on Berthing and Departure of 200,000-ton Container Ships in Dalanping Port Area of Qinzhou Port. Port & Waterway Engineering, 10, 19-22. https://doi.org/10.16233/j.cnki.issn1002-4972.20220927.008

[3] Li, M., Mou, J., Chen, P., Chen, L., & van Gelder, P. H. A. J. M. (2023). Real-time collision risk based safety management for vessel traffic in busy ports and waterways. Ocean & Coastal Management, 234, 106471. https://doi.org/10.1016/j.ocecoaman.2022.106471

[4] Debnath, A. K., Chin, H. C., & Haque, M. M. (2011). Modelling port water collision risk using traffic conflicts. The Journal of Navigation, 64(4), 645-655. https://doi.org/10.1017/S0373463311000257

[5] Marroni, G., Moreno, V. C., Ovidi, F., Chiavistelli, T., & Landucci, G. (2023). A methodology for risk assessment of LNG carriers accessing vulnerable port areas. Ocean Engineering, 273, 114019. https://doi.org/10.1016/j.oceaneng.2023.114019

[6] Linjun Zhao, Chenggang Tang, Jibin Tang, Jilong Chen & Yinna Wu. (2023). Safety analysis of large LNG ship mooring under severe working conditions. China Water Transportation (Next Half Month). (08), 6-7+10.

[7] Lin Huxin. (2023). Safety operation of passenger-roll-on vessel in and out of port in case of strong convective weather in the Qiongzhou Strait. Nautical Technology, (03), 6-10.

[8] Liao Dongjie. (2024). Berthing maneuvering of ships at berth 13C in Jiangyin Port Area of Fuzhou Port. Water Transportation Management, (06), 37-40. https://doi.org/10.13340/j.jsm.2024.06.002

[9] Song Li, Wenhua Wu, Weian Yao. (2024). Research on Bayesian model correction method for semi-submersible platforms based on measured data. Journal of Ship Mechanics, 28(02), 179-190.

[10] Xuesong Zhou. (2022). Effective Use of Escort Vessels for Cruise Ships Entering and Leaving Shanghai Port. Marine Technology, (06), 5-8.

[11] Jingxian Liu, Yuanqiao Wen. Simulation of port channel passing capacity based on ship behavior characteristics [J]. Journal of Dalian Maritime University, 2009, 35(02): 31-33+37. https://doi.org/10.16411/j.cnki.issn1006-7736.2009.02.011

[12] Tao Xuebing. Discussion on berthing and unberthing methods of Yongzhou container terminal. China Water Transportation (the Second Half of the Month), 2017, 17(10): 27-28+104.

[13] Chen Donghua. Analysis of factors affecting the safe berthing and unberthing of ships and operation techniques. Pearl River Water Transportation, 2023, (16): 6-8. https://doi.org/10.14125/j.cnki.zjsy.2023.16.004

[14] Wang Zijian. Safety study on berthing and unberthing maneuvering of large container ships in heavy wind and waves. Pearl River Water Transportation, 2021, (11): 83-84. https://doi.org/10.14125/j.cnki.zjsy.2021.11.036

[15] Qiang Wang, Qiulin Luo, Wenjing qu. (2020). Comprehensive Risk Analysis of LEC for Tunnel Construction Safety Based on Fish bone Diagram Approach. China's New Technologies and Products, (21), 140-142. https://doi.org/10.13612/j.cnki.cntp.2020.21.049

[16] Chang Dehua. Exploration of optimization of water traffic organization--Taking the construction of a branch channel of a harbor pool as an example. Transportation Enterprise Management, 2024, 39(02): 106-108.

[17] ZHANG Bin, ZHENG Zhongyi, FENG Baoming, et al. A review of research on ship traffic organization in complex waters. Science, Technology and Engineering, 2022, 22(27): 11774-11782.

[18] Fang Hao, Wang Haixiang & Ke Ranjian. (2024). Construction and realization of a knowledge base for berthing and unberthing of large ships. Journal of Jimei University (Natural Science Edition), (02), 134-141. https://doi.org/10.19715/j.jmuzr.2024.02.05

[19] Liu Tong. (2019). Analysis of navigational risk and response of Rongjiang waterway in east Guangdong. Navigation Technology, (05), 26-30.

[20] Liu Junliang., Ding Minqiang. & Guo Riyi. (2024). Research on water traffic safety management regulations for ships in bridge area waters. China Maritime Safety, (01), 66-68. https://doi.org/10.16831/j.cnki.issn1673-2278.2024.01.021