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Risk assessment of marine traffic safety at coastal water area

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Abstract

With the rapid development of the maritime industry, maritime traffic safety management in China is under great pressure. Recently, it is obvious from the safety management on aft-causalities to risk assessment on proactive management of marine traffic at coastal water area. According to the investigation of safety situation at coastal water area of China, applied on Formal Safety Assessment (FSA) approach which was held by International Maritime Organization, the characteristics of hazards and accidents at coastal water area were analyzed and some results of risk distribution were held out in quantities. Furthermore, some proposed risk control options (RCO), synergy-based management mode by grid or cell, and long-term strategy in Coastal Water Area were carried out, which included hazard identification, risk evaluation, crisis early-warning, emergency handling and decision-making of RCO.

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1. Introduction

One of the main concerns of ship stakeholder including shipbuilders, ship owners, ship operators and maritime administrations is the safety of ships at coastal water area. There are enormous penalties for the lack of safety, in terms of lives lost, damage to the environment and cargo, which should all be avoided from the shipping industries. This has been reflected in the attention given both to the building activities, the operation of ships, education and training of ship operators [1]. However, the use of formalized approaches to quantification of risks in maritime field has lagged somewhat behind other field, such as the nuclear and the aerospace for an instance, in which often with very high severities of causalities have promoted the adoption of these methods.

The safety culture of anticipating hazards rather than waiting for accidents to occur has been widely used in other industries such as the nuclear and the aerospace industries. The international shipping industry has begun to move from a reactive to a proactive approach safety through what is known as Formal Safety Assessment (FSA) [2]. The papers [3-5] discussed that FSA tool was viewed as a new tool at the aspect of risk management, and the papers [6-9] demonstrated that some kinds of vessel safety were analyzing with FSA tool. The papers [10-12] analyzed the marine traffic safety using fuzzy or probability math for quantitative assessment. The paper [13] held quantitative risk assessment and generic risk model in FSA, especially frequency and severity criteria for vessel navigation. Then it put forward a new model based on relative risk assessment (MRRA).

To further promote the work of marine traffic safety, using the safety assessment comprehensive principle and method of FSA, investigation, further discussion, in-depth research and analysis have been adopted in recent years for the risk analysis of coastal water traffic safety in China coastal water area and its causes. After the completion of these tasks, some
recommendations to improve traffic safety and promote traffic safety strategy to protect against the risk measures was held out, including risk prevention system and mechanism for risk control by means of management methods and models.

2. Safety assessment on marine traffic at coastal water area

Based on the full research and analysis investigation for marine traffic at coastal water, safety situation and development trend, risk prevention, safety regulation and other aspects of a summary and analysis have been presented, combined with the actual needs of coastal vessel traffic and marine traffic safety at coastal water area in China, conclusions of which are as follows.

2.1. Safety pictures about marine traffic at coastal water area

China’s coastline has the long length of $3.2 \times 10^4$ kilometers which includes mainland coastline of $1.8 \times 10^4$ kilometers and off land coastline of $1.4 \times 10^4$ kilometers. As in some straits and islands, coastal waters became one of the most important channels for north-south ocean shipping in China. Since the reform and opening of China, the mainlands economy has been rapidly developing and cross-strait communication has been deepened. China’s shipping economy has changed dramatically, with shipping and cargo throughput showing rapid growth trend. Vessel traffic has the following characteristics:

1. The categories of ships are of great variety; and with uneven situation, traffic density has boomed;
2. Vessel traffic has been increasing rapidly, especially for large tonnage vessel, whilst risk in marine traffic is even greater;
3. Dangerous goods transport ships and vessels have been increasing rapidly, resulting in increased risk of pollution from ships;
4. Increasing number of ships across the strait has raised the risk of cross-strait direct transportation.
5. Inter-island, strait transportation will continue to increase, whereas it will significantly increase risk of passenger loss;
6. There are 9 kinds of accidents or casualties which are collision (connected or unconnected), contact, stranding, aground, sinking, fire or explosion, weather harm, indirect collision, etc except for pollution.

With time goes by, the quantity of reported accidents has decreased rapidly, but the loss of property has increased several times (see Fig 1). Along the coast areas, collision accident is the major category of marine traffic accidents which occupies 60 percent in the total statistic data.

Fig. 1. Statistic data of China marine traffic accidents from 1980 to 2011.
In addition, the Strait's location for traffic impact is very prominent, and this determines that China’s coasts are vulnerable to attacks from northeast monsoon, tropical cyclones or fog effects. As a result, it is growing into the three meteorological characteristics. Furthermore, bridge construction has become increasingly prominent for vessel traffic; engineering vessels, sand carriers and other small vessels are also significant for the coastal vessel transport.

China Maritime Safety Administration (MSA) has been engaged in fruitful work for safety supervision and management. Moreover, in the ship operating and water safety supervision area, the administration system has formed a set of relatively complete and effective administration systems. The routine Vessel Traffic Management System (VTMS) has played an active role in most coastal water areas in China. As a result, marine traffic at coastal water area has always been relatively safe.

2.2. Risk evaluation on marine traffic at coastal water area

In terms of safety, risk is the object to describe the amount of risks, which is mainly focused on the risk of adverse events within the system as abnormal events and the risk as the possibility of a harmful event occurred or the consequences of the normal level of events leading to injury. Risk is of double characteristics with frequency and consequences degree \[2,13\]. The FSA method of quantitative calculation about risk \[13,14\] has been adopted, and vessel traffic risk assessment in coastal water area has come to the conclusion \[15\] that:

1. The overall situation of China coastal vessel traffic is very fair, and the risk level is in ALARP region. The accident ratios in monsoon, foggy and typhoon seasons are 5.2, 6.4 and 4.6 respectively in ten thousand. The average consequence in various seasons varies from 1.42, 1.79 to 1.88 based on the general severity of accident (seriously injured or equivalent property loss). Furthermore, the marine traffic risk has been reduced in evidence especially in the past three years. The risk at coastal traffic in foggy season is much higher and less steady than the one in other seasons like typhoon and monsoon.

2. The relatively higher risk was mainly distributed as follows: Foggy – offshore (beyond the baseline but within 10nm) - collision, Foggy-fairway/coastal-collision; Monsoon – fairway/coastal-collision, monsoon- near pier – contact; Typhoon - fairway /coastal-collision; Typhoon - fairway /coastal- aground.

3. After verifying reliability compared with the risk characteristics of marine traffic in different periods, the additional risk also need to be considered as follows: Monsoon- offshore – aground; Foggy- coastal – aground; Foggy - near pier- contact; Typhoon- anchorage - collision.

4. 9 kinds of accidents or casualties show different strength about risk characteristics. The collision, contact, stranding and grounding mainly focus on frequency nature while fire or explosion, sinking, weather harm and wave indirect collision mainly focus on severity nature. That means data statics may play key role in risk analysis on collision and contact while case study may be taken into account in risk analysis on fire or explosion and sinking.

3. Risk copying in marine traffic at coastal water area

3.1. Risk copying mode and strategy design of marine traffic at coastal water area

3.1.1. Synergy-based risk copying mode

In order to conduct comprehensive coastal water traffic risk copying for each designated location, the paper proposed Synergy-based mode risk copying \[16\] (See Fig 2). According to the risk reduction measurements, this mode divided the risk controller into three different levels: manager, operator and supporter. The process of risk reduction based on temporal relationship was divided into three stages: before the accident, in progress and after the accident. All the risk controllers and stages are integrated into the proposed mode.

In dimensions of the spatial pattern in this model, management level, operation level and support level are not regular. They vary with different risk events and different severities. In certain risk reduction project, personals at all levels are addressed clearly to their own positions and responsibilities, so as to improve the response speed to the target.

In dimension of temporal relationship, also in this model, before the accident, in progress and after the accident \[16\] are the processes of risk events which are occurring, developing and eliminating. According to the risk system of marine traffic, the processes of risk reduction activities \[16\] include avoidance, monitoring, early warning, response and recovery. Risk copying based on synergy can be done through time, while the following shall be observed:

i, before the accident, emphasis on the following activities such as prevention, and monitoring

ii, appropriate close the accident, emphasis on the following activities such as early warning;

iii, during the accident, emphasis on the following activities such as emergency response;

iv, after the accident, emphasis on the following activities such as recovery and continuous improvement.
3.1.2. Risk precaution system in marine traffic

The risk precaution system refers to a certain structure, gradation and forms of documentation system, which is related to the safety alternative or related composition of the overall safety awareness. This system was designed based on the risk and characteristics of coastal water, and establish an effective system to avoid or reduce the risk of vessel traffic, at last in forming regulation or procedure, table or checklist, to improve risk management level. The system aims to realize life first of all, by establishing clear responsibilities, authorities and interests, in order to focus on efficiency and innovation in risk precaution on marine traffic.

Currently focused on the risk of vessel traffic, the risk precaution system includes the internal management level:

i, at the process of Risk Identification, controlling system of hazard to safe vessel traffic in coastal water area;
ii, at the process of Risk Assessment, reputation management system of safe vessel traffic in coastal water area;
iii, at the process of Risk Copy, the effective measures of safety administration system for the shipping company including avoidance, retaining, transferring and eliminating;
iv, at the process of Risk Response, emergency response system of safety vessel traffic in coastal water area;
v, at the process of Risk Review, continuous improvement of safe vessel traffic in coastal water area.

3.1.3. The risk precaution long-term strategy

Risk precaution long-term strategy, or mechanism, is an integrated regulation with technique, or the institutionalized method. The system has its own independent form of existence whereas the mechanism is not an independent regular form, often being involved in certain system. The risk precaution long-term strategy is the inter-relationship and mutual effect process and methods between the various parts of the normal operation risk copying. Based on the purpose for risk reduction in a mass of marine traffic, it is imperative for the Maritime Safety Administration to transit from the special rectification to a long-term strategy. It is also essential to establish a combined management mechanism between daily management and special rectification.

Currently focused on the risk of marine traffic, the risk precaution long-term strategy includes the view of external management level:

i, at the aspect of Enforcement, to further improve safety administration documentation system;
ii, at the aspect of Responsibility, to establish responsibility system of vessel traffic in ship operating;
iii, at the aspect of Engineering, to establish a reliability system of vessel aiming to maintain marine traffic safety;
iv, at the aspect of Education, to improve a safety mechanism for public education and training system;
v, at the aspect of Economics, to promote the economic investment in safe guard of marine traffic sub-system.
3.2. Synergy-based Risk Copying Mode of marine traffic at coastal water area in China

The risk of marine traffic at coastal water can be controlled from the accident safety monitoring system. Any accident formation has latent, growth, critical and outbreak period [16]. According to modern safety management, risk management should be the intervener and supervisor for the whole process. Therefore, the risk copying of marine traffic at costal water area could be carried through three periods: before the accident, during and after the accident. The Synergy-based risk copying mode of vessel traffic in coastal water area must be built with the consideration of all processes. The demand for risk copying of marine traffic at coastal water area is the synergy-based mode between the participants and accidents process supervision, not only request the participants to cooperate with the management-level level, operating officers and support staff, but also request the connected time and process in risk precaution. In accordance with the HAZOP (hazard and operability analysis) principle [16], the risk copying system and mechanism of vessel traffic in coastal water area was actualized based on synergy mode (Synergy-HAZOP). They are subdivided into two parts:

i, The early-warning procedure of marine traffic at costal water area in China has respective measures for three levels of staff who work to avoid the accident.

ii, The response, recovery and continuous improvement procedures of marine traffic at costal water area in China has respective measures for three levels of staff during and after the accidents once happened [16].

4. Risk decision-making of marine traffic at coastal water area

4.1. Risk control options of marine traffic at costal water area

Risk management of marine traffic at costal water area is a process to achieve "harmony maritime" safety culture goal, which aims at the safety of vessel traffic, applying effective use of resources, to develop the ability of the staff who work for the system of vessel traffic in costal water area, and to make efforts to ensure that all crews can stay comfort with the ship equipment, cargo and different environment, to reduce or eliminate the risk of production safety. This management is a cycle dynamic process. Risk management involves hazard identification, risk assessment, early warning, emergency response, and continuous improvement which makes the risk management of vessel traffic in costal water area continue to improve. Risk copying of vessel traffic in costal water area continues to develop toward a higher goal, so that the system of vessel traffic in costal water area can achieve optimum safety level.

The statistic analysis for the accident of marine traffic at costal water area in China shows that most accidents happened near the coast or in harbor, and that the accident damages were mainly caused by collision and contact. Therefore, based on the traffic accident in one of the costal water area, it’s an effective management measure for risk prevention using the "GRID" or cell management for this water area.

The grid management of marine traffic at costal water area is based on the synergy mode by the region, which can be divided into 4 tiers including large, middle, small and mini regions or grids [17]. According to different emergency scale and extent of injury and the influence degree or scope in marine traffic, some information was used to determine the risk rank of early warning information, with which the risk rank of early warning information from low to high is divided into four levels of early warning signal (see Fig. 3), namely, level 4 warning (blue), level 3 warning (yellow), level 2 warning (orange), and level 1 warning (red). According to the early warning range and level, corresponding grid (one or several) of lattice shall be consistent with the warning signal color.

Finally, the initial hazard should be emphasized to strengthen the nature of safety management and environmental protection in costal water area. The engineering theory of marine traffic at costal water area is reviewed on vessels, crews, shipping company and navigation environment that may affect the vessel traffic safety in costal water area.

4.2. Recommendation for the risk copying of marine traffic at costal water area

Statistics of the ship activities since 2000 has indicated that marine traffic accident rate remains in the level of about $10^{-4}$, if dependent on the reference standard [13] as the consequences of less serious accident (the basic standard loss is average loss) in Chinese Statics Regulation which is seriously injured or equivalent property loss, the risk ranking lies in the level of $10^{-3}$ above. Then the risk of person death (based on HSE criterion) lies in the level of $10^{-4}$ above accordingly. These data have demonstrated that the supervision of marine traffic at costal water area has been changed from the traditional type of emergency salvage after the accident to a comprehensive risk copying before the accident.
With the rapid development of the maritime industry, maritime traffic safety management in China is under great pressure. With the increasing serious situation in maritime safety, ship stakeholders have realized that the effective coastal water transport risk management is of greater importance, and they have started to establish the appropriate risk management systems. However, risk management in marine transportation is still in its infancy, with institutional barriers and legislation seriously lagging behind, while lack of professionals is one of the main problems.

5. Conclusion

Based on real data collection, statistics and analysis of nearly 10 years on the accident of marine traffic at coastal water area in China, and full investigation to understand the basis of the relevant situation, FSA variety of techniques was adopted on vessel traffic in China to conduct a comprehensive analysis and discussion, and some conclusions were obtained in coastal water transport safety and risk assessments. Especially for the safety factor of marine traffic at coastal water area, using a risk assessment model on the actual investigation and analysis of research domain, the paper was combined with many years of maritime experience of effective supervision in China, and recommendations were proposed on risk copying strategy and safety management of marine traffic at coastal water area. The application is also a new attempt which put the FSA method used in the safety management of marine traffic at coastal water area [18-20], and the results show that this method is conducive to resolving risk assessment based on historic cases.

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