Study of ship piloting risk aversion based on human reliability analysis

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Abstract: Ship pilotage is an important part of ship transportation. The safe and smooth operation of berthing, leaving port and transferring berths is the guarantee of economic and safe development of port waterway transportation. The potential safety risk of pilotage operation will bring potential safety hazard to port water transportation service. It is of great significance to keep the pilotage service safe, efficient and stable, to prevent the occurrence of vessel pilotage accidents and to meet the needs of port development. The risk assessment of ship pilotage is an important method to reduce pilotage risk and avoid safety accidents. In this paper, the operation of ship pilotage is discussed, According to the supervising party, the operator and the interest party involved in the pilotage operation, the structure chart of the pilotage system of the ship is constructed. Reason Swiss cheese model and human reliability analysis is used to analyze and model Ship pilotage risk, this leads to the risk issues that require priority attention, and then the measures to reduce the risk of pilotage are proposed.

Keywords: ship pilotage, risk assessment, Swiss cheese mode, human reliability analysis, FTA

1. INTRODUCTION

As china's "maritime power strategy" and "the belt and road strategy" implemented step by step, promote the rapid development of china's port shipping economy, and then lead to an increase in the number of ships to the port. Thus, the number of pilotage vessels in china's coastal ports has increased dramatically.

At the same time, with the improvement of the functional division of coastal ports in China, the specialization, division and operation of bulk cargo, crude oil, liquid chemicals, containers and so on, and the specialization of ships are becoming larger and larger, More and more new ships, ship scale and tonnage are increasing, which brings a lot of risks to ship piloting operations in coastal ports.

In the complex, including navigable waterway ship ship's number, scale and speed, maneuverability problems such as uneven, increase the pilotage of harbor of the difficulty and intensity, resulting in increased risk of pilotage.

According to statistics, only six months, a harbor area waters occurred in general and above the level of water traffic accidents 15, 16 wrecks, missing four people died, the accident caused by direct economic losses of 162 million yuan.

Pilotage is an indispensable part of port security and service. It is an important component of international shipping and the first image of water port. To speed up the construction of production and large ship berths large pace at the same time, in order to ensure the rapid development of port economy, to ensure the ship pilotage smoothly, attached to the ship pilotage safety, it is very important to study the risk management of ship pilotage.

The potential safety risk of the pilotage of the pilotage is drawn from the development of the pilot service. The safety risk factors of the pilotage process are classified and analyzed. The main causes of each risk are analyzed, and the prevention suggestions are studied from both internal and external risks. Aiming at the main risk, the way of restraining is put forward.

Table 1 The path of human reliability research

Keywords	The describe of research
Pilot psychological	Effect of the pilot psychological quality on the pilot operation
The "rhythm"	Effect of the "rhythm" on the pilot operation
Pilot comprehensive	Effect of the pilot psychological and physiological stress levels, and skills on the pilot operation
Pilot and execution environment	Effect of the pilot comprehensive quality and execution environment on the pilot operation

The above historical researches only consider the pilot, without considering the whole operation, or only consider a single mission. In this paper, in the course of pilotage, from the human starting point, consider overall the pilotage system, and put forward the corresponding suggestions to reduce the risk.

2. SHIP PILOTAGE SAFETY MANAGEMENT POLICY

In the context of the state's attention to safety in production, the Ministry of transport strengthens the specific implementation of pilotage safety management. In November 2004, the Ministry of transport issued the "Circular on further implement the safety responsibility management mechanism" (Haifa to pilot [2004]613) as soon as the preparation of "ship pilotage safety management system requirements of the pilotage institution". In November 2005, the Ministry of transport issued the "notice on Further Strengthening the safety management of the pilot, to further clarify the pilotage institution, the administrative department of port, maritime bureau in ship pilotage safety management responsibilities. The Ministry of transport in May 2007 issued "Circular on Strengthening China's port pilotage management" (the water [2007]174), put forward the port administrative departments should focus on the establishment of pilotage safety work, safety procedures and safety management system, the maritime administrative agency should strengthen supervision and management of pilotage safety work. The maritime administration department in January 2011 issued the "Circular on Further Strengthening the pilotage safety supervision work" (sea security [2011]31), further supervision, branch of Maritime Bureau maritime bureau directly under the requirements of the organization to the location of the pilotage institution guidance institutions to establish and improve the safety management system, safety management system in accordance with the relevant requirements of document No. 613, 2004.

In accordance with the spirit of the above-mentioned three documents, the pilotage institution has formulated the ship pilotage safety management system according to its operation situation, which belongs to the internal safety management document of the pilotage institution. But in fact, there are many external factors for the safety of ship pilotage. The external factors, such as the berthing conditions of the port, the navigable conditions of the channel and the changes of hydrology and meteorology, have an important impact on pilotage safety. Safety precautions of pilotage, in construction, the internal management system to enhance the technical level of pilotage institution at the same time, must coordinate; grasp the changes in the external environment, the maximum degree of pilotage safety accident prevention. Therefore, the risk assessment of ship pilotage has important practical significance, and has a strong guiding role in preventing the occurrence of ship pilotage accidents.

3. RISK MANAGEMENT

Risk management is a series of activities that recognize the potential risk factors that may exist in the system, estimate the possibility of these factors and the effects resulting from them, and prevent or reduce the adverse effects. Risk management, including four stages, which is risk identification, risk assessment, risk control and countermeasures research.

Risk management is a new management discipline. Since 1981, China's Ministry of labor and personnel has organized to study of safety evaluation for the first time, and to introduce HSE management system of petroleum industry. The national standard GB24353-2009 and the principle of

risk management and implementation guidelines risk management has gradually been highly valued by various industries.

Risk is the product of the probability of occurrence of an accident and the outcome of an accident. Any risk is controllable, as long as the scientific design of risk control program strictly enforced, you can avoid the occurrence of security incidents. The same is true of ship pilotage safety. Although the complex internal and external environment is involved, the safety risk can be controlled if effective measures are taken.

4. RISK IDENTIFICATION

Risk identification is the risk factor that may exist in the defined system, and what impact these factors have on the system.

On the basis of full understanding of risk characteristics, identify potential risks and specific risk factors of these risks.

Risk identification is generally combined with standard analytical techniques for application. Identification of an ex post or existing danger should also take full account of the anticipated risk of impending or imminent danger.

Pilotage features and potential safety risks, sources of large-scale development of ships and rapid development of ports. The tonnage of the ship and the main scale becomes larger, the difficulty of the operation of pilotage technology gradually increased; the rapid development of the port, the number of daily arriving ship will continue to increase, the pilot ships will increase year by year, the pilot work intensity is increasing year by year.

4.1. Risk factors

Along with the development trend of large-scale international shipping, cited ton ships become larger and the main ship gradually larger scale, increase the difficulty of the pilot, piloting the ship berthing operation technology challenges. The pilot needs to overcome the large tonnage ship pilotage on psychological pressure, while the large tonnage ship operation need to accumulate technical experience, resulting in the increase of pilotage risk. Large tonnage and large scale ship increase makes the actual demand to the high level of the pilot increased, part of the port has pilot level and actual ship scale uncoordinated phenomenon.

The number of cited ships increases year by year with the increase in port throughput, and pilots need to face more pilot mission requirements, working hours and work intensity increased. Inland waters, the berths of berths are tight, and there are many vessels in the fairway, and the operating environment is complicated. The increase in the number of pilots and the number of shipments of the pilot ship did not match the increase; the number of personnel in the pilot team is insufficient, resulting in a significant increase in the workload of the pilot.

The above two factors pose a risk to pilotage. The risk factors, according to the boundary division of risk, can be divided into internal and external risks, the internal risk refers to the events in the internal organization, and external risk refers to the risk of occurrence in the main external organization.

4.2. Pilotage risk

According to this classification method, pilotage risk is divided into two categories, internal risk and external risk.

Internal risks are including the pilot process of human risk and internal security management risk. The analysis of the status of the pilot are including the health level, the degree of fatigue, the degree of emotional control, the degree of safety awareness and the quality of the mind, as well as the pilot

experience of the pilot knowledge, including the pilot laws and regulations, the degree of development familiarity of the program and contingency plan, the degree of awareness of the environmental condition.

Table 2 Category of human behavior of ship accidents

Type of behavior	The describe of behavior characteristics
Skill behavior	There is a very close coupling between the input of information and the response of the person. It does not entirely depend on the complexity of a given task. It only depends on the level of personnel training and the experience of completing the task.
Regular behavior	Controlled and controlled by a set of rules or programs, the main difference between it and the skill type is the understanding or mastery of practice. If rules are not well tested by practice, people must repeat and proofread each rule. In this case, people's reaction may be caused by short time, slow cognition process and poor understanding of rules.
Knowledge behavior	Under the fresh environment of unclear symptoms, conflicting or completely encountered situations, operators do not have any existing rules. They must rely on their own knowledge and experience to analyze, diagnose and make decisions.

The internal security management risk of the pilot process is including the risk of the management personnel involved in the pilot accident process. Through the analysis and judgment of historical data, the following table of factors affecting the collision is summarized.

Table 3 The influence of human and organization factors during the operation for pilotage

human factors			**organization factors**		
Ability		Behavior	Train	Management	
Perception error	Error of action	Error of action	Technical training error	Mismanagement of resources on ship	Collective error

For external risks, it includes the risk factors of the ship and the risk factors of the external environment. Among them, the risk factors of ships can be divided into the risks of the cited vessels and the risks of tugs, as well as the risks of other ship equipment on the pilotage accidents, as well as the risks of the crew members and captains of the ship being cited. The risk factors of the external environment and environment factors, detailed for the waterway anchorage risk, dock risk, the risk of traffic (that is caused by the density of ships on the route of accident factors), risk information sharing, he cited the risk (the ship around the ship non normal sailing accident caused by the risk. Especially the accident caused by dredging and fishing boats crossing route) and pilotage accident natural factors influence risk factors.

4.3. Risk ranking

Usually due to speeding, collision and extrusion caused by the cited ship, terminal equipment and personnel constitutes a minor danger, did not cause significant losses, The danger with such accidents classified as dangerous security Pilotage; For the cause of major casualties and property damage classified as a ship pilot safety accident. Through the study of the accident and danger cases which have a certain representative and characteristic in the course of a pilotage in the past 10 years, it is concluded that In addition to the risk of natural factors, the risk of channel anchorage and the risk of cited shipments are the first, his ship risk ranked second, tug round risk ranked third.

The results also show that the risk of external risks in the lead pilot, in addition to natural factors cause the risk, the risk of his ship in the first row, cited the ship risk ranked second, channel, anchorage and port risk ranked third.

According to the operation place of vessel pilotage, pilotage risk can be divided into pilotage risk in port, pilotage risk in pilotage channel and pilotage risk in anchorage. The study shows that the risks in the port area are more than those in the channel, and the risks in the channel are more than those in the anchorage.

Most of the accidents and dangers in the harbor area are mainly caused by the risk of the cited ship, the risk of the crew; the cause of accidents and dangers on the waterway is mainly the risk of his ship; Occurrence of accidents and dangers in anchorage, mainly due to the risk of natural factors. Internal and external risk statistics Pilot accident and danger, the results show that: the pilot system external risk is greater than the pilot system internal risk.

5. Risk assessment

Based on human behavior and organizations theory, Reason proposed the “Swiss cheese” model. There are many holes in the interior of Swiss cheese. A safety system that runs interlocking accurately is like a stack of Swiss cheese, each cheese represents a line of defense, and the holes on cheese are potential system vulnerabilities. Most of the threat will be stopped by a piece of cheese, but if the hole happened to a stack of cheese into a straight through. The channel equipment personnel illegal, arrhythmia, plus internal system problems not repair or may be a threat to break through layers of the garrison, eventually evolved into a major accident. FMEA and FTA have been widely used to analysis the “Swiss cheese” model.

The risk assessment is on the basis of risk identification, the corresponding index system and evaluation standard, to classify the degree of risk, reveal the key risk factors affecting the security of the system, according to the key risk factors, take preventive measures, to reduce the risk and improve the existing security situation. At the same time, through this assessment, relevant risks can be kept within the acceptable range as much as possible.

The main process is based on the numerical results of various risks; choose appropriate risk analysis, and the results of the comparison, through the analysis of the risk assessment of the classified "negligible" and "unacceptable" and "acceptable risk" three different risk categories. Through the risk assessment, we can identify the high-risk areas for different types of risks, identify the main factors that affect the level of risk and explain the scope of the results of the analysis. The risk evaluation method is used to evaluate the risk of ship pilotage, including the possibility of risk occurrence and the consequence of risk. The classification is given in table 4.

Table 4 Risk of the possibility and severity of the accident

Possibility		**Severity**	
Occurrence frequency,	Existing control measures	Consequence severity	Accident consequence cause loss
High	No control measures	Very serious	The pilot station is unable to handle itself
Middle	Without any control measures	Serious	The pilot station can do it by itself.
Low	Control measures,	Commonly	Each branch of the pilotage station can handle it by itself
Very low	Occasionally there are mistakes	Slight	An accident that has not reached above average

5.1. FMEA analysis

Risk assessment is based on the seriousness of the likelihood and the consequences of the risk event, and the risk value is equal to the product of the likelihood and severity. Risk assessment of risk accident cases where risk events are in acceptable risk areas. For the main risks, the failure modes are

established according to the failure modes, failure effects and failure causes of the case,which is given in table 5.

Table 5 Vessel pilotage main risk FMEA form

Failure mode	Failure effect	Failure cause
Collision	Collision bridges, cables and ships, property damage, casualties	The trend of complex, low visibility, anchor tension, high traffic density, narrow channel
Grounding	Loss of waterway traffic and property caused by collision	The anchor ship has many narrow channels, submerged reefs and rapids
Break the cable	Touch berth, park difficulty, property damage	The pre berth flow pressure difference is larger, the hull draft is large, and the water depth is smaller
Be stranded	Loss of waterway traffic and property caused by collision	The chart data is inaccurate, the tide is complex and the berth is tight
Be out of control	Property damage, casualty	New vessels operating equipment is out of order and malfunction
Anchor dragging	Property damage, casualty	Anchorage water sediment condition is poor, easy to drag during high winds and high tide
Collision	Collision bridges, cables and ships, property damage, casualties	The trend of complex, low visibility, anchor tension, high traffic density, narrow channel

According to the accident evaluation table, the Risk Priority Number (RPN) was calculated based on the accident probability, severity and control capability, which can be used to evaluate the failure mode of the FMEA table. According to ALARP principle diagram, divided into three areas of risk severity, risk acceptability and risk negligible area, distinguish the risk region of failure mode.

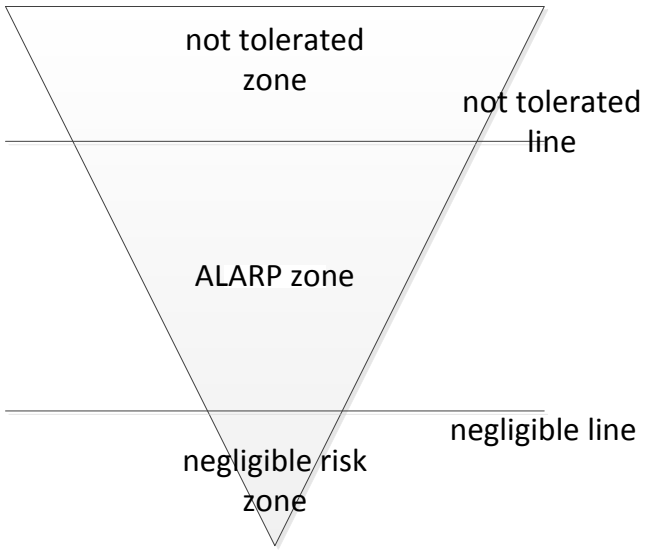

Fig. 1 ALARP principle diagram

By risk assessment, collisions, striking a reef, mooring failure, aground, incontrollable and dragging anchor, these 6 failure modes are all in reasonable risk range.

5.2. FTA analysis

The FTA model belongs to the logical causality model. According to the principle of cause and effect, the causal relationship between risk and its causes is shown. The FTA model is a tree like logic causality diagram of the inverted stand. By using the method of logical deduction and reasoning, the failure causes of the system can be clearly explained. The ship's pilot fault tree model is set up, for detail ,see figure 2 . The symbols in the picture are detailed in Table 6.

Table 6 The basic events and code names of the risk model

code	Event	code	Event
A1	Ship related technical conditions are not good	B3	Lack of technical experience
A2	Personnel (crew, pilot) and behavior Lack of knowledge	B4	Weak sense of safety
A3	Poor external environment	B5	Poor physiologic condition
B1	The technical condition of the cited ship is not good	B6	Poor mental state
B2	Tug technology is not in good condition	B7	Poor work style

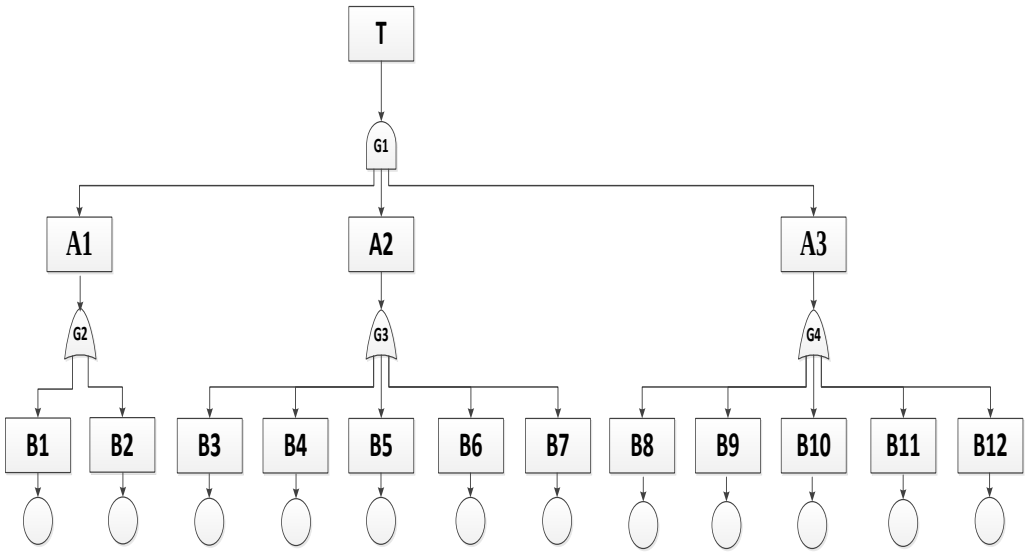

Fig. 2 A model diagram of the fault tree of a ship's pilotage

The FTA analysis finds out the causes of events that predict and identify potential risk factors in the early stages of the event, according to the reasons for the logical relationship generated by the event. FTA analysis, finding the measures to avoid risk by finding the cut sets and the path sets in the FTA model. In the FTA analysis, the minimum path set is obtained on the basis of the cut set, and the result is shown in Table 7.

Table 7 The result of the minimal path set analysis

Serial number	Analysis results
1	{ B1+B2 }
2	{ B3+B4+B5+B6+B7 }
3	{ B8+B9+B10+B11+B12 }

The structure importance is solved by using Boolean algebra. The results are shown in Table 8.

Table 8 Structural importance ranking results

Serial number	Analysis results
1	{ B1+B2 }
2	{ B3+B4+B5+B6+B7 } { B8+B9+B10+B11+B12 }

Through the analysis of FTA, we can see that there are 3 minimum path sets in 50 minimum cut sets. There are 50 Ways to cause the risk top event of the ship's pilotage. There are 3 direct ways to control

the risk of a ship's pilotage. According to the calculation of the importance of the structure, 3 minimal path sets, order of importance, where {B1+B2} is the most important minimal path sets, The most important degree of the path is set {B3+B4+B5+B6+B7} and set {B8+B9+B10+B11+B12} is the same important. The risk control of the minimum path sets {B1+B2} should be paid attention to.

6. Risk control scheme

The risk control scheme is based on the risk identification and risk assessment, the paper puts forward the corresponding measures of risk reduction, risk control scheme and according to these measures feasible, including the formulation and revision of some regulations. In the risk control plan should carefully consider the known risks and in danger of "recognition" and "risk analysis" risk identification in step two, we should be fully aware of the risk as a result of new technology or update the operation method of the cause, so as to fully implement the risk control scheme for all. These risk control schemes, such as standardizing operation procedures, formulating rules and regulations and strengthening training, should prevent accidents from occurring or mitigate the consequences and impacts of accidents.

In the process of formulating risk control scheme, we must first clear the need to control the risk area, and according to the actual situation of these risk areas to develop risk control measures are feasible; then the risk control measures to be refined and the formation of operational risk control scheme, including the formation of new or revised procedures and regulations; at the same time that should be carefully identified risks and countermeasures adopted in the new risk control scheme possible. When necessary, the risk generation tree analysis method can be used to reevaluate the risks arising from each risk control scheme being adopted. The risk level, the frequency of the accident and the severity of the consequences should be taken into account in the evaluation. When the risk level reaches "unacceptable", the accident should be resolved, and the areas where the highest probability of occurrence of the risk and the most serious consequences of the accident will be dealt with seriously. At the same time, attention should also be paid to finding areas of greater uncertainty in risk levels, consequences, severity, or probabilities.

The risk control scheme of ship pilotage can be formulated by systematic method. Based on the improvement of ship pilotage safety management system, using the principle of system engineering, by controlling the risk of the operation of the system; improve the pilot training mechanism, through the theory and practice of training to enhance the technical level of the pilot; use of information management, strengthen risk prevention and control. At the same time, each risk source is identified in the form of risk control list for risk identification, and the overall level of ship pilotage risk is lowered by controlling each item.

7. Countermeasures and suggestions

For the security risks within the pilot station, it includes management risk and man-made risks. For the management risk, we can strengthen the pilot skills training, strengthen the pilot team building, and strengthen the daily safety management, and in the management system version, maintenance, upgrade embodied in the three strengthening. Through the internal perfect safety management system, regularly to pilot station safety management system assessment, combined with the characteristics of the pilot work, the pilot operations in each stage of specific operating procedures, as a guide to action pilot activities. To resolve the responsibility, safety management responsibilities, safety specifications, safety regulations and procedures to develop detailed guidance, to regulate pilotage operations management, operations, pilot training and improving the quality of has a complete set of rules and regulations and operation mechanism.

To achieve the pilot air safety responsibility and security management procedures to prevent management risk. For artificial risks, can strengthen the construction of safety culture; enhance the safety awareness of the pilot. Establish safety management policy and set up general objective of safety management. To the overall goal, the implementation of the annual pilotage safety goals, water

and road traffic safety goals, pollution prevention targets, fire safety and other specific targets. Guard against human risk.

For ship pilotage, the main risks are ship risk and environment risk. Through the establishment of pilot operation procedures, including the different regions of the navigation and collision avoidance, anchoring methods and precautions, make different port wharf berthing tug, berthing operation essentials, develop the corresponding berthing time, operation time, guidelines and reference for the implementation of pilot operations, pilotage safety work instruction fine, reduce the external risk of pilotage.

Vessel risks include the risks of tugs and the cited ships. The standard of pilotage tug service is set up to facilitate the tugboat company to standardize pilotage service and reduce the risk caused by tugboat. Strictly control the entrance of the overdraft vessel and reduce the risk caused by the ship being taken. Two measures to prevent vessel risks in external risks.

Environmental risks include ship risk, traffic flow risk, wharf condition risk and channel anchorage risk. Increase investment in science and technology and information sharing, to deepen the pilot scheduling system and the convergence of VTS, VTS to expand the coverage and timeliness of monitoring, to grasp the situation of traffic flow in the process of pilot navigation area, the external risks in his ship risk and the risk of traffic. It is convenient for port operators to regulate the tonnage of ships to the port, so as to meet the requirements of pilot scale, and to avoid the risk of wharf conditions in external risks. Strengthen the technical core function of pilot station in navigation demonstration, and make the pilot institution participate in the technical scheme demonstration of pilot external environment change. The changes in the external environment for pilot can fully consider the risk of pilot operation, at the same time the pilotage institution can grasp the changes of pilot external environment, the external risks in waterway anchorage risk.

8. Conclusions

In accordance with the procedures and methods of risk management, the pilotage of risk identification and risk assessment, the corresponding risk factors and main risks, and puts forward the pilotage risk control scheme, puts forward the countermeasures and suggestions, the corresponding results can be used as reference for the risk management of ship pilotage.

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