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A study on navigation safety on Putou Branch Channel extension project for Meizhou Bay

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A STUDY ON NAVIGATION SAFETY ON PUTOU BRANCH CHANNEL EXTENSION PROJECT FOR MEIZHOU BAY

By

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THE DECLARATION

I certify that all the materials in this research paper that are not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this research paper reflect my own personal views, and are not necessarily endorsed by the University.

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ABSTRACT

At present, Putou is an important port area of Meizhou Bay port. With the development of the port construction and the industry cluster in Meizhou bay, Putou port's navigation shipping quantity and the port throughput has significantly increased Putou branch waterway navigation of the ship scale and its transport capacity has not met the demand of the development of the port. From the perspective of the promotion of local economic development and the demand of the throughput development, according to the plan, Port Authority of Meizhou Bay in Fujian province had formulated the construction plan of the engineering of navigation waterway in Meizhou bay. Based on this, it can be believed that the Putou branch waterway will be constructed in the near future.

In order to enhance the navigation safety during the engineering construction, it is necessary to make scientific analysis of and evaluation on the Putou branch waterway extension engineering of Meizhou Bay .In a way, this evaluation could also provide basis to supervise the MSA.

Based on Putou branch waterway extension engineering, include 70,000 DWT waterway projects and 10,000 DWT projects, first of all, combined with the waterway project location, project general situation carries on the analysis of the port waterway environment and the forecasting analysis of the waterway traffic flow; secondly, the degree of interplay between the engineering and the natural environment should be analyzed, the port environment as well as traffic environment; thirdly, the method of fuzzy comprehensive evaluation to the waterway engineering navigation safety evaluation should be applied, judged to be relatively safe; finally, we put forward some measures for reducing risks. At the same time we point out that since the security is a relative concept, various factors may change as may the environment changes, security measures also cause accidents.

KEYWORDS: Meizhou Bay port Putou Branch waterway extension engineering fuzzy comprehensive navigation safety evaluation

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LIST OF ABRREVIATIONS

AIS	Automatic Identification System
COLREGS	Convention on the International Regulations for Prevention Collisions at Sea
DGP	Differential Global Positioning System
DWT	Dead Weight Tonnage
FTA	Fault tree Analysis
GT	Gross Tonnage
MSA	Maritime Safety Authority
NM	Nautical Mile
RTK	Real-time Kinematic
SEM	Structural Equation Modeling
VHF	Very High Frequency
VTS	Vessel Traffic Services

CHAPTER 1 INTRODUCTION

1.1 Research Background

More than ninety years ago, Sun Yat-sen, a great revolutionary forerunner, pointed out in *The International Development of China* that the Meizhou Bay is one of the six uniquely excellent natural ports in China (Shi,2012, pp. 1-9). Located in the central Fujian Province, it is commonly regarded as one of the three largest bays in Fujian Province. Along with the rapid development of port economy in China, the Meizhou bay (See the figure.1) is now provided with 65 productive berths and 23 of them bigger than 10, 000 DWT. What's more, there is also two 300,000 DWT crude oil berth. The handling capacity of Meizhou bay is more than a million tons. There is navigation waterway of 86 kilometres available now, which can satisfy the navigation requirements of 220, 000 DWT coal ship, Q-Flex-styled LNG ship, 300, 000 DWT VLCC and 5000 TEU container vessel (Port Authority of Meizhou Bay, 2015). Therefore, it plays an important role in opening itself to China's South-East coastal area, promoting the economy development of Middle and West Region of China and enhancing the exchanges and cooperation with Taiwan (Wu, 2013, pp. 124-126).

Up to now, some major ports and waterway engineering that are under construction(See Figure.1) include: 400, 000 DWT specialized iron ore port in the China's South-East coastal areas; state-invested coal supply-hub with the annual total handling capacity of 8000,000 Tons; supporting port for the refining engineering of Sinochem Group; the first "enclave Port" engineering cooperated between Jiangxi Province and Fujian Province, the import-export base for the liquid chemicals; the 300,000 DWT navigation waterway with the largest investments and highest level ever since in Fujian Province (Port Authority of Meizhou Bay, 2015).

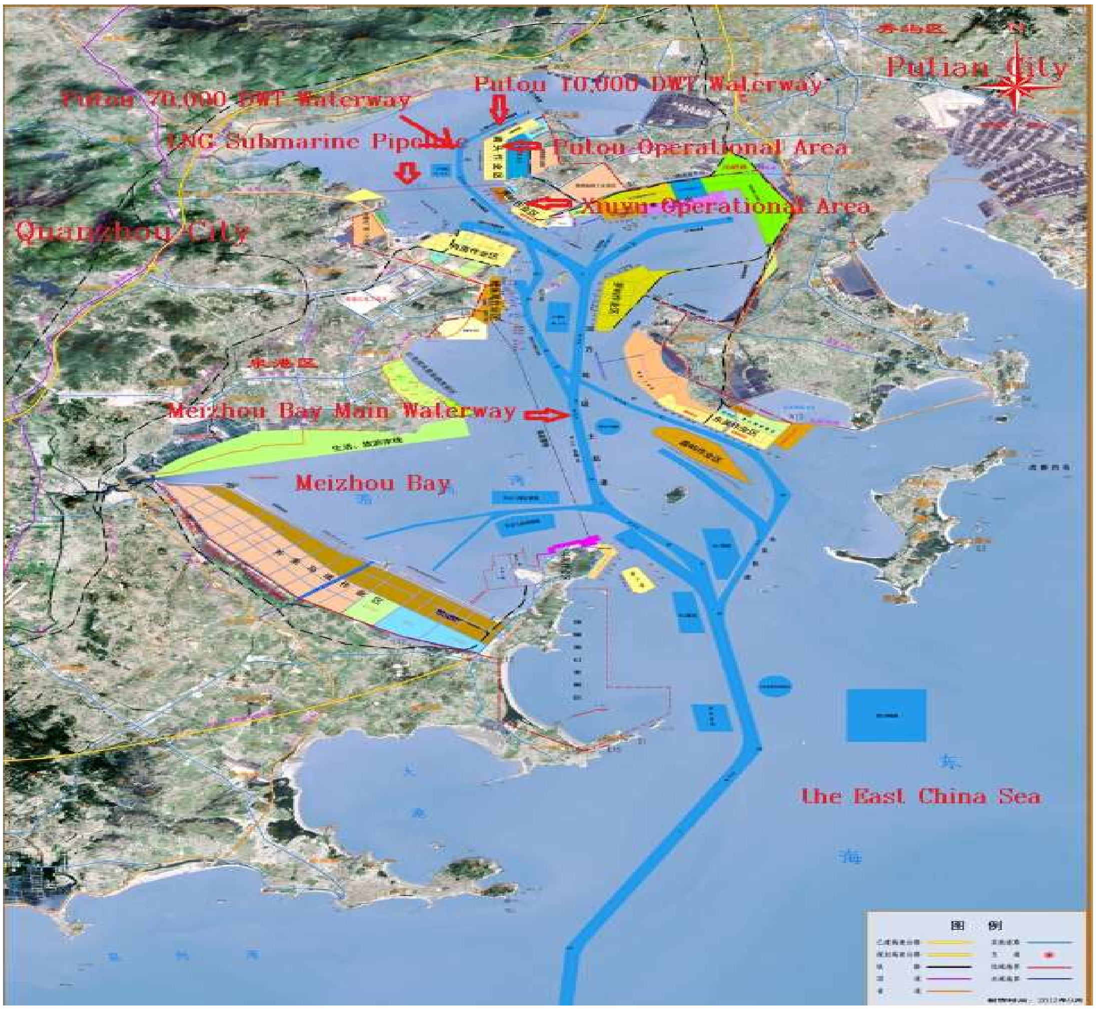

Figure.1- The general planning maps of ports and waterways in Meizhou Bay

Source: Retrieved 10 June 2015 from the World Wide Web:

http://www.mzwgk.gov.cn/gkgk/gkjs.html

The cargo handling capacity of those new ports in Meizhou bay will reach 120,000,000 Tons and total handing capacity will also be up to 200,000,000 tons by the end of 2017. Until then, Meizhou bay is capable enough for the navigation and parking of various kinds of bulk cargo ships, such as the 400, 000 DWT iron ore carriers, 450,000 DWT crude oil Tanker, 220,000 DWT coal carrier and Q-MAX-styled LNG carrier etc.(Fujian Port &Waterway Investigation & Design Institute, 2011).

Although Meizhou bay is undergoing a rapid development, its navigation waterways can not satisfy the ever-increasing demands for the moment and in the future. The extension engineering of main navigation waterways and branch navigation waterways are under construction or just around the corner. With the great navigation intensity, the complicated traffic flow and the new building engineering of ports, navigation waterways, the navigation situation of Meizhou bay is not that optimistic and is confronted with an increasing number of risks, such as the vessel traffic accidents and the pollution of seas etc.

Putou Branch Waterway Engineering is one part of the navigation waterways engineering of Meizhou Bay. This branch waterway is very important because it connect s the Putou operational area and the main navigation waterways. It is close to the operational area of Xiuyu General Port and LNG port and is just opposite to the Xiaocuo operational areas. The extension engineering of Putou Branch Waterway Engineering will adopt such methods as the reef explosion and mud dredging, which is certain to have an impact on the operation of such surrounding ports as general cargo ports, chemical cargo ports and crude oil ports etc. That the reef explosion shall give special attention to those areas within 200 meters of the submarine pipeline of LNG increases the risks of construction. In order to effectively lower the incidence of traffic accidents within the port district, it is necessary to conduct a research on the navigation safety in the extension engineering of Putou Branch waterway. The safety assessment can not only provide basis for delimiting the scope of construction and traffic control area, but also serve as a reference for the maritime management strategies during the construction period.

1.2 The Objectives

The Extension Engineering of Putou Branch Waterway is a part of the engineering of navigation waterway in Meizhou bay, which includes the following two aspects: Expanding of the current 50, 000 DWT branch navigation waterway into 70,000 DWT through the dredging of navigation and reef blasting engineering; Building of 10,000 DWT navigation waterway in the north-west of Putou port operation area (Water Transport Planning and Design Institute of China, 2011).

That the construction can change the navigation environment and conditions will, to a certain extent, have an impact on the navigation safety and relevant marine facilities. In order to avoid or lower the undesirable effects of construction on the navigation safety, guarantee a safe navigation environment and guard against the possible pollution of surrounding waters, it is important to strengthen the effectiveness and pertinence of maritime management. Based on this, this paper is intended to conduct a research on the navigation safety of Putou Branch Waterway Extension Engineering through a qualitative and semi-quantitative analysis of it, focusing on analysis of the potential risks of navigation safety while implementing the engineering and put forward suggestions to lower the navigation risks as well as effective measures to guarantee the navigation safety, in order to reasonably utilize the navigation resources and guarantee the safety of terminal operation and navigation safety of the surrounding waters.

1.3 The Current Research Status of Navigation Safety Research

1.3.1Overseas research on navigation safety

Kobayashi H. puts forward evaluation methods of the marine traffic environment safety with difficulty rate in ship handling as the indicator, and proposes in "*Impact of Ship Handling Characteristics on the Navigation Environment Safety Evaluation*" to evaluate the difficulty rate in ship handling within the whole maritime space through quantitative analysis of the impact of the change of ship type, ship length, water depth, wind and other conditions on the ship handling ability (Kobayashi H., 1995). ARAI Yasuo quantifies the natural environmental factors influencing the ship handling ability with the index values and analyzes the relationship between these indexes and the feeling of the ship handling personnel, thus providing reference for the objective judgment of the impact of various factors on the navigation safety as well as the improvement of the navigation environment (ARAI Yasuo, 1997). Kinzo Inoue proposes a quantitative model to evaluate the ship safety navigation in restricted areas or areas of traffic congestion (Kinzo Inoue, 2000, pp. 167-180). Yip T.L. Proposes to establish a traffic flow model based on the traffic flow theory, which has been applied already (Yip, 2013, pp. 109-113).

1.3.2 Domestic research on Navigation Safety Research

Domestic research on navigation environment has obtained leap development. The SEM is integrated by path analysis, factor analysis and other general statistical and testing methods, which can solve the complexity of the variables and make quantitative analysis of the causal relationship between variables (He, 1997, PP. 36-41). According to the uncertainty of expert scoring in evaluation, it introduces the concept of expert credibility. Based on this, it also studies the composition method of the uncertainty conclusion and quantifies the expert uncertainty. Professor Zheng Zhongyi analyzes the eight environmental factors affecting the ship safety navigation in Grey Evaluation Mathematical Model of the Port Ship Navigation Environment Risk Degree by using the grey system theory and index fixed weight clustering method. On this basis, he carries out safety evaluation of the ship navigation environment in part of China's coastal ports (Zheng, 1998, PP. 318-321) . With the use of the FSA method and through the analysis of the various factors endangering the safety management of coastal waters (Zhao, 2005, pp. 77-78), This paper gives a brief introduction to the fuzzy comprehensive analysis and then expounds each influencing factor respectively after handling the data in the expert questionnaire. This paper also establishes a corresponding membership function and establishes a fuzzy comprehensive evaluation model by integrating these influencing factors.

1.4 The Main Task

1) Combined with the geographical location and general situation of the waterway engineering, analyze the port waterway environment and make prediction analysis on the future traffic flow development of the waterway; analyze the mutual influence between dredging engineering and navigation environment as well as the navigation impeding.

2) Analyze and study the mutual influence between the waterway engineering and the natural environment, traffic structure and port facilities and function;

3) Evaluate the navigation safety of this waterway engineering with the method of fuzzy comprehensive evaluation and draw the final conclusion of the navigation safety of this waterway engineering;

4) According to the above research and analysis, propose rational suggestions on the waterway extension engineering construction.

CHAPTER 2 GENERAL INFORMATION OF NAVIGATION ENVIRONMENT ANALISYS

2.1 Geographical location

2.1.1 The Position of this Engineering

This engineering is located in the Putou operational areas in the Meizhou Bay of Putian in Fujian Province and the geographical approximate position is 118°58'29.1" E,25°13'28.8"N.

2.1.2 Overview of the Engineering

This engineering is mainly composed of the following aspects: the dredging and reef blasting of Putou's 70, 000 DWT branch navigation waterways and the dredging of 10, 000 DWT branch navigation waterways in the Northern Putou operational areas. The whole construction period lasts about 18 months.

The Putou 70,000 DWT branch navigation waterways are about 200 meters wide and the designed depth is -11.0 meters. The tiding water level for ships of design types entering port is 5.66 meters high and could last two hours. The designed cumulative frequency of high tide level is 90%. The total navigation waterway is about 4.9km and this waterway is expanded based on the 50,000 DWT navigation waterways that have been completed in January 2013. According to current data of water depth, the extension engineering will be carried out near to the submarine pipeline of LNG and the construction area shall be at least 125m from the submarine pipeline of LNG.

The 10, 000 DWT navigation waterways in the North of Putou operation area is 100 meters wide and 4.8 meters high. The tiding water level is 5.66m high and it can last two hours. The cumulative frequency of high tiding level is 90%. The total navigation waterway is 2.9 km long. Based on the current date of water depth, this sea area is mostly shallows, with the water depth ranging from 2 to 6 meters. The deep-water area is relatively narrow.

During the construction, it will adopt the following constructing method:

(1) $8m^3$grab dredger will be employed during the construction and the total mud dredging is about 130,500m;

(2) Employing the cutter suction dredger and the total dredged mud is about 6,867，666 m^3.

(3) 600 GT reef-explosion vessel will be employed and the total exploded reef is 44,400 m^3.

2.2 Analysis of Natural Conditions

Meizhou belongs to the subtropical climate and this paper will analyze the meteorological data collected by the Xiuyu meteorological station over the past years.

2.2.1 Meteorological Condition

The rainy season of Meizhou bay is between May and June, with the annual precipitation being 640.2 mm. There is fog from November to the next May . The prevailing wind is mainly Southern wind in summer and Northeast wind in other seasons, with the average wind velocity being 7.15 m/s. The direction of strong wind is Northeast wind, with the greatest wind velocity being 27 m/s. Based on the date of Xiuyu meteorological data, there are, on the average, 18.4 days of above-7-grade wind throughout the whole year (The navigation guarantee department of the Chinese navy headquarters, 2009).

2.2.2 Hydrological Condition

The sea area has the regular semi-diurnal tide. The tide level and range is characterized by the following rule: Water level gradually increases from the inner bay to the outer bay while in high tide, or otherwise, with the average tide range being 4.65 m and the greatest tide range above 7m.

Owing to the geographical conditions, Meizhou bay is basically the reversing flow and the direction of rising or falling tide is basically consistent with the grooves of sea bottom. The flowing velocity of big tide is bigger than that of small tide. Likewise, the flowing velocity of surface tide is great than that of underlying tide. The maximum flowing velocity of the cross section of Xiaocuo-Xiuyu is measured to be 1.85m/s (The navigation guarantee department of the Chinese navy headquarters, 2009).

2.2.3 Geology and Physiognomy

There are many reefs in the sea bottom of construction area and other parts are mostly mud-and-sand sediments. The amount of sand-and-mud sediments is basically equivalent to that of water erosion.

2.3 Analysis of Navigation Conditions

2.3.1 The Conditions of Wharfs in the Meizhou Bay Ports

Meizhou Bay Port is composed of the following four ports, namely, Douwei Port Area, Dongwu Port Area, Xiuyu Port Area and Xiaocuo Port Area. Putou operational area is located in the sea area of Xiuyu Port Area. The submarine pipelines of LNG divides the Putou Port and Xiuyu Port, with the Putou port in North. For the time being, the berth 1# and berth 2# has been completed while berth 3#－6# are under construction. The Putou operational area can be divided into the following several parts: General wharf, Multi-purpose wharf and Bulk & General-cargo wharf. There are eleven 10,000 DWT berths in the general wharf and multi-purpose wharf, which constitutes the 2181m wharf lines. Bulk & General-cargo wharf is close to the multi-purpose wharf and it is expected to build fourteen 5,000 DWT-10,000 DWT berth in the future. When it is finished, Putou operational area is reached to import 24800, 000 tons of goods annually and 500, 000 TEU containers.

2.3.2 Navigation Waterway

At present, those main navigation waterways within Meizhou Bay include:

(1) 250, 000 DWT main navigation waterways within Meizhou bay, which fall into the following two parts: outer part of navigation waterway is 300, 000 DWT Qinglan

Mountain navigation waterway of Oil Refinery in Fujian Province, which is 500 meters wide and 21-23.0 meters high. Inner part of the navigation waterway within the bay has the effective width of 300 meters, and the height of 18.3 meters, which can satisfy the requirements of one-way navigation of 250, 000 DWT bulk carriers during the rising tide period (The navigation guarantee department of the Chinese navy headquarters, 2010).

(2) 100, 000 DWT branch navigation waterway for the Oil Refinery in Fujian Province.

(3) Dongwu 100, 000 DWT branch navigation waterways.

(4) 100, 000 DWT branch navigation waterway in the west of Huiyu.

(5) 50, 000 DWT branch navigation waterways in Yangyu.

(6) 50, 000 DWT branch navigation waterways in Putou.

(7) 100, 000 DWT branch navigation waterway in Xiaocuo.

2.3.3 Anchorage and Navigational Obstructions

There are altogether 9 anchorages, with five within the bay and two bays at the mouth and outside of the bays separately. Sometimes, such navigational obstructions as fishing net etc can be found in the navigation waterway. There are also shoal nearing the construction (The navigation guarantee department of the Chinese navy headquarters, 2010).

2.4 Ship Flow

2.4.1 Current Flow of Ship

In 2014, total 4,816 ships arrived in and departed the Meizhou Bay port, and cargo throughput of port increase to 70,890,000(Fujian Meizhou Bay Port Authority ,2015).

2.4.2 Flow of ships in Future

It is predicted that cargo throughput of Meizhou Bay port will reach to 90,000,000T at least (Fujian Meizhou Bay Port Authority, 2015). Based on the calculation of the data of 2014, ship traffic flow will reached 6122 in 2015.

2.5 Chapter Summary

This chapter first introduction the overview of the engineering, this engineering includes two parts. One is the dredging and reef blasting of Putou 70, 000 DWT branch navigation waterways, and the other is the dredging of 10, 000 DWT branch navigation waterways. And then put forward the Specifications and technical requirements of the waterways .After that, analyzed the natural conditions, meteorological condition, hydrological condition and geology and physiognomy condition. At last, give some information in navigation environment about the waterways area, and traffic flow of ships.

CHAPTER 3 ANALYZING THE NAVIGATION OBSTRUCTION AND ITS INTERPLAY WITH NAVIGATION ENVIROMENT

3.1 Analysis of Navigation Obstruction

3.1.1 Analysis of the navigation obstruction of Putou 10,000 DWT branch navigation waterways during the construction period

3.1.1.1 The Anchoring Waters of Construction Vessel

The construction of Putou 10, 000 DWT navigation waterways is mainly composed of the dredging of mud in the navigable waters and the 2000 m^3/h cutter suction dredger is employed and occupies the 150m waters in width during the construction period, namely 75m on either side. The construction vessels and the sludge discharge area are connected by 360 m long pipelines.

3.1.1.2 The Interference of the construction Vessels with the navigation of other Vessels

During the construction period, the construction of vessels can interfere with the navigation of the passing vessels, and the scope of navigation obstruction is not limited to the working waters of construction vessels and its anchorage devices, namely the 150 m waters in width. The mud-discharging pipelines are floating on the surface of the water, which constitutes the navigation obstructions for other passing vessels. For the time being, no cargo ships, except some small fishing ships, will navigate through the waters. In the meantime, warning signs will also be placed near the construction vessels. However, it is expected that the construction will not have obvious impact on the other vessels.

3.1.2 Analysis of the Navigation Obstruction of the Construction of Putou 70, 000 DWT Navigation Waterway

3.1.2.1 Working Waters of Construction Vessels

The construction of 70,000 secondary navigation waterways is mainly composed of the reef explosion and mud-dredging. The reef explosion area is mainly within a radius of 1320 m of wharf's turning water area and the reef-explosion vessels are moored by six anchorages. Two of them are separately fixed by the anchors in the fore and back of the vessel, with the anchor chain of 100-200m long and the rest are separately fixed on either side, with the anchor chain of 80-150 m long. RTK-DGPS will be employed to position the construction vessels during the underwater drilling. In order to lower the impact of construction on the navigation of passing vessels, the construction shall begin from one side and then the other side while exploding the reef. The anchor chain can be adjusted to lower the impact of construction in low-tide line on the navigation of passing vessels.

The explosion and clearance of reefs shall be carried out in high-tide level to avoid the rubbles splashing out of waters. In accordance with the Safety Specifications of Blasting Practices, the safety distance of blasting can be calculated through $R=(K/V)^{1/\alpha}\bullet Q^{1/3}$ (Chen, 2007,pp.36-39).

Q: Quantity of one-time detonating explosives (kg);

R: Safety Distance from blasting point to other targets (m)

V: Blasting seismic safety speed (m/s)

K, α: Coefficient related with the geologic condition of blasting point, attenuation index

The maximum quantity of one-time detonating explosives of this engineering is set at 100kg. Based on the geologic condition of sea bottom, it can be calculated K=150,α=1.5,Q=100kg,m=1/3.

The shortest distance from LNG submarine pipelines to blasting point is 285 m and the reinforced concrete structure will be adopted in this engineering. The blasting seismic waves will have the greatest impact on the LNG submarine pipelines and the maximum resultant vibration velocity of LNG submarine pipelines is 3.0 m/s. According to the calculation results, $V＝KQm^{\alpha}/R^{\alpha}$=0.6cm/s, which is less than the safe vibration velocity.

Those vessels that are within a radius of 1000 m from the blasting point are prohibited from navigating through the waters and the construction vessels shall be at least 150 m from the blasting point.

In clearing away the rubbles of blasted reef and dredging the mud, their range of construction is similar to that of 10, 000 DWT secondary navigation waterway. Thus this paper won't discuss it in great detail due to the limitations of space.

3.1.2.2 Analyzing the Navigation Obstruction of Reef Explosion

Owing to the fact that vessels will berth and depart from Fengting operational area and Putou berth 1# and berth 2 # in the Meizhou Bay Port, the reef blasting will have certain impact on the navigation of those ships. Before the underwater blasting, the people in charge of the construction shall first apply to the maritime administrative agency for the required safety waters of blasting in order to issue navigational notices for mariners (Fu, 2011,pp.184-186).

Before the reef explosion, the construction team shall make plans for the construction, determine the quantity of explosives reasonably and design the drilling holes, in order to avoid or reduce the underwater flying rubbles. After the reef explosion, the unit shall pay attention to its sphere of affect on the underwater flying rocks. In addition, in working out the reef blasting plans, the constructors shall take into account the time spent on clearing away the reef and shorten the interval time between reef explosion and reef clearing. Besides measuring the scope of reef explosion after the clearance of submarine rocks, it is supposed to expand the scope to at least 50m from the reef blasting area.

In order to reduce the interplay of reef blasting and reef clearance and improve the efficiency of construction, it shall explode the reef on a large scale and then concentrate on clearing away the exploded reef. The intersection construction shall be avoided. The construction vessels shall first clear away the blasted reef rocks of one side of the navigation waterway and then the other side. Some of the waters of navigation waterways can be taken up, which is certain to have certain impact on the navigation of mercantile vessels and fishing vessels of the surrounding waters.

In terms of the mud-dredging, dredger shall be anchored the open moorings within the navigation waterway and the anchor chains are about 150 m long. The required waters for the operation of dredgers will certainly take up part of the navigation waterway, which is likely to affect the entry-and-departure of commercial vessels in Putou berth # 1 and berth #2 and Fengting operational area or the passing fishing vessels in the surrounding waters. Therefore, those vessels shall navigate through the waters with caution.

3.2 Precautions in the Construction

To reduce the impact of construction on the navigation of other vessels, it is suggested that the construction of navigation waterway shall be divided into two areas with the central-line of navigation waterway as the demarcation line based on the concrete situations of navigation waterways. The construction shall begin with the construction of one area and then the next area. Taking into account the tide level and concrete conditions, large vessels can navigate through the waters in the high-tide level and small vessels can navigate through the waters in the low-tide level. In order to guarantee the navigation safety, it is suggested that:

(1) The construction of each area shall be alternately carried out based on the tide level

(2) The length of cable from the anchor casted by the construction vessel to cable buoy shall be based on the actual tide level.

(3) The dredging will have certain impact on the navigation safety of vessels. Observation of those passing vessels during the construction period shall be strengthened and the contact with the construction vessels to track their positions through the communication waterways, which makes it possible for others vessels to proactively avoid the construction vessels

(4) The anchors on the navigational sides shall be moored into the deepest part of waters. The construction shall be temporarily stopped and loosen the anchor chains of the navigational side in order to reduce the impact of navigation obstruction when there are the passing vessels.

3.3 The Interplay of Construction and Natural Environment

3.3.1 Impact of Natural Environment on Construction

The wind has a huge impact on the construction and thus the construction shall be immediately stopped when the measured wind force is above the moderate gale or anti-wind grade of construction vessels. In carrying out the construction plan, the conductors shall pay attention to the weather forecast and changing trend of weather Meizhou Bay Port is subject to the typhoon from July to September. During the typhoon season, pre-arranged plans for the construction shall be made to prepare for the coming of typhoons and lower its negative impact (Chen, H. W., 2012).

Meizhou Bay Port has many foggy days from March to May every year. The fog is heavy outside of the Bay and lighter inside of the Bay. The construction shall avoid those foggy months. When the visibility is less than 1000 m, it shall stop the construction. Safety precautions shall be taken in those foggy days with poor visibility when it is under construction.

The construction near LNG submarine pipelines shall pay attention to the impact of flow on the construction vessels. When the tide waves changed, the constructing ships should be re-positioned by DGPS to secure a safe distance from LNG pipelines.

3.3.2 Analyzing the Impact of Construction on the Natural Environment

In dredging the navigation waterways, it can result in the suspended mud and sand owing to the mechanical disturbance of bottom sediments and the leakage of sludge, which can increase the turbidity of seawater and pollute the seawater. In the process of dumping the dredged mud, the discharge of tail water can increase the turbidity of water near the discharge outlets. However, the water can recover after the construction. The dredging and reef blasting will permanently change the landscape of sea bottom near the construction. The garbage produced by the construction vessels, the sanitary sewage and oily water can pollute seawater and those pollutants shall be discharged into the receiving devices on land. Additionally, the dust emitted by the construction site and the waste gas discharged by the vessels can pollute the air (Zhou, B., 2007, pp.57-60).

3.4 Chapter Summary

This chapter is mainly composed of two parts. The first part put forward the navigation obstruction of this engineering caused by the construction ships and their devices like anchors and pipes. It is important to note that at the time of reef blasting, and traffic control should be implemented. It also gives some suggestions to reduce the impact of construction on the navigation of other vessels based on the construction methods. The second part analyzes the interplay between the construction and environment. The heavy weather like dense fog ,typhoon, etc. It is not conducive to the construction. However, the construction result in the suspended mud and sand owing to the mechanical disturbance of bottom sediments and the leakage of sludge, There is no doubt that it will change the marine environment. The dredging and reef blasting will permanently change the landscape of sea bottom near the construction. There also exists some risk of sea pollution.

CHARPTER 4 RISK EVALUATION OF NAVIGATION IN THE CONSTRUCTION WATERS

4.1 Methods in navigation safety evaluation

4.1.1 General introduction

Navigation safety evaluation is that in order to control the potential risk and reduce the system risk to a level which could be accepted and meet the expected navigation safety requirements, we analyze, evaluate and predict on the whole navigation environment system qualitatively and quantitatively(Wu, 1993, pp.11-15). The Figure 2 is a follow chart of evaluation on navigation safety, which uses the method of comprehensive judgment, the steps are as follows:

Fist, it should determine the risk evaluation index on the basis of the marine traffic investigation; and then formulate the corresponding safety evaluation standard; at last ,get the evaluation result through comparing the risk level of navigation environment with certain standard(See Figure 2).

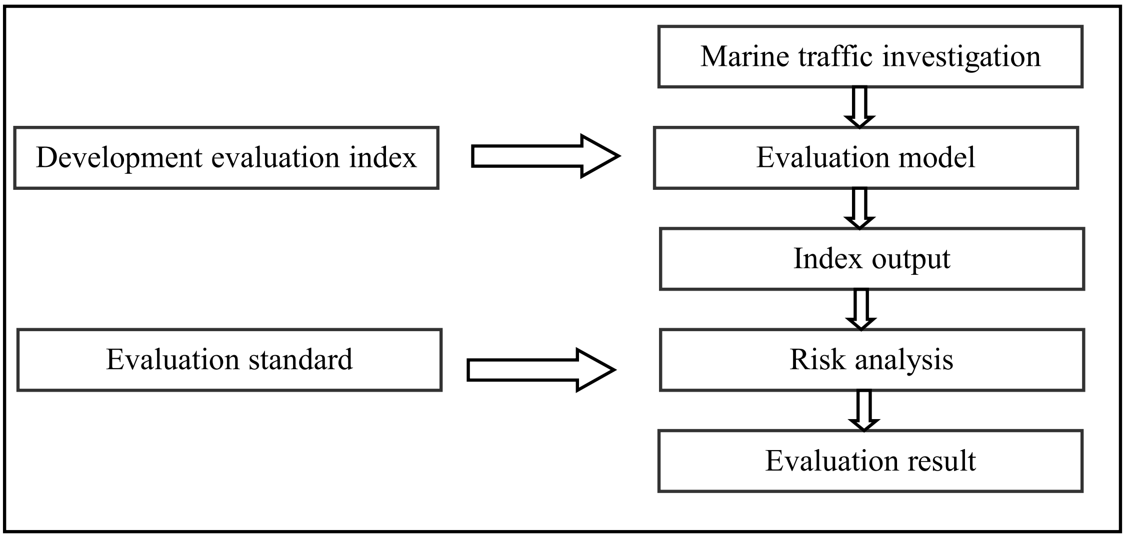

Figure 2 – Follow Chart of Evaluation on Navigation Safety

Source: He C. H. (2013). Research on navigation safety of 50,000 Tones channel for Haiyang district in Yantai port. Dalian: Author.

4.1.2 Methods of navigation safety evaluation

As an emerging research field, safety evaluation is a branch of science which needs to use the multidisciplinary knowledge and integrates and applies that knowledge in the evaluation process. Disciplines relating to navigation safety evaluation mainly include statistics, system engineering science ， operational research， etc.. There are many method used in navigation safety evaluation, as Safety Index Assessment methods, grey system theory , fuzzy evaluation method, analytic hierarchy process , comprehensive safety evaluation, probability risk assessment method, artificial neural network evaluation method, data envelopment analysis method and evidence theory are very common.

(1) Safety Index Assessment

To work out the percentage of the accidents caused by various factors in the total number of accidents, the general statistical analysis is to employ the regression analysis, principal component analysis and correlation analysis method to conduct analytic statistics of the number of maritime accidents caused by various causes or the number of weighting accident conversion (such as endowing the accident grade with the weight coefficient). Many scholars and maritime management departments reckon the danger level of the inland river navigation safety based on the number of accidents practically occurring in the water area through Safety Index Assessment (Wu., 1993). However, Safety Index Assessment has a defect, that is, the sample size in use must reach certain accumulation number. The probability distribution chart thus obtained is relatively more stable, and the model and conclusions are also more useful under the situation. Though the quantitative analysis of some maritime accidents can also be solved through the above methods, the number of maritime accidents causes cannot reflect the correlation between these causes and accidents due to the above defect. Besides, the statistics reveal that a large sample size is needed and the sample distribution must meet certain requirements to obtain the desired conclusion. Obviously, the practical operation is relatively difficult.

(2) Grey System Theory

When an established system cannot obtain lots of information, Grey System Theory can be adopted. Grey System Theory adopts the correlation analysis to measure the information obtained according to the similarity or dissimilarity degree of the development trend between various factors, and to conduct an in-depth research and analysis of the information to obtain the desired conclusions. While analyzing the danger level of the navigation safety, many scholars adopt Grey System Theory for the following three reasons. First, the correlation between various factors constituting the navigation environment is not clear. Second, the small probability events and data which affect the navigation channel safety are hard to be collected comprehensively. Third, the internal navigation environment structure is not clear and is hard to set the simple mathematical and physical models (Wen, 2003).

(3) Fuzzy Mathematics

Fuzzy Mathematics is a mathematical method to study the fuzzy phenomena. The basic assessment method of Fuzzy Mathematics is to choose several factors of the assessment object, and comprehensively consider the influence of the object's various factors to establish the assessment index system. The assessment standard for various index factors can be confirmed according to the practical assessment requirement, and the membership function of every index factor can be confirmed to undergo single factor assessment. Then, according to different weights of various factors, the fuzzy conversion principles, the fuzzy recognition methods and corresponding subjection principles are employed to build the mathematical model for comprehensive assessment. Through the mathematical model, the research object is comprehensively analyzed (Zheng, 2008, pp. 130-131).

(4) Analytic Hierarchy Process

Analytic Hierarchy Process is a qualitative and quantitative systematic and hierarchical analysis method(Dey,2003, pp. 213-221).

The basic steps of analytic Hierarchy Process are:

1) Build the hierarchical structure model;

2) Constitute the pairwise comparison;

3) calculate the weight vector and conduct the check consistency;

4) Calculate the compound weight vector and conduct the pairwise comparison. If the pairwise comparison passes, the decision can be made according to the result expressed by the compound weight vector; otherwise, the model should be reconsidered or some pairwise comparison matrixes with a higher consistency ratio can be restructured (Zhao, 1997, pp. 40-45).

(5) Formal Safety Assessment (FSA)

As a structured and systematic platform, Formal Safety Assessment aims at providing favorable support for the maritime safety decision-making based on the risk analysis and cost-benefit and enhancing the maritime safety. In the recent years, FSA has been a new model for navigation risk assessment. It contains five standardized steps, including risk recognition, risk assessment, risk control plan, cost-benefit analysis and suggestions for decision-making (He, 1997, pp. 36-40).

(6) Probability Risk Assessment

Probability Risk Assessment requires the data to be correct and sufficient, the analysis process to be complete, the judgment and hypothesis to be reasonable. Due to the complex methods, the wide range of the navigation system, the serious lack of the system safety knowledge and data, the practical application has certain difficulty (Zhang, 2003, pp. 53-56).

(7) Artificial Neural Network Assessment

Artificial Neural Network Assessment is to find out the internal relation between the input and the output and obtain the assessment results through learning and training, and according to the data provided instead of the experiential knowledge and rules of the problem. Thus, the method has the self-adaption function, which can contribute to the weakening of the influence of artificial factors to confirm the weight or the membership degree function (Mao, 2011, pp. 62-65).

(8) Data Envelopment Analysis

Data Envelopment Analysis is to employ the mathematical programming model to compare the relative efficiency between the decision-making units and to assess the decision-making units. From certain perspective, the decision-making units have the same input and output. Through the comprehensive analysis of the input and output data, the quantitative index of the comprehensive efficiency of every decision-making unit can be obtained. Based on that, various decision-making units can be lined up to confirm the valid (namely with the highest relative efficiency) decision-making units and point out the reasons for the invalidity of the other decision-making units and their invalidity degree. Data Envelopment Analysis can also judge whether the input scale of various decision-making units is proper, and provide the accuracy direction and degree for various decision-making to adjust their input scale. Data Envelopment Analysis is employed to assess the superiority of the relative validity of the assessment department. It cannot be replaced by the other methods (Zhuang, 2005). In other words, the relative validity assessment based on the large-scale input and output in the social economic system has unique advantages. Its defect is that it only suggests the relative development index of the assessment unit but cannot show the practical development level.

(9) Evidence Theory

Evidence Theory was first put forward by Dempster in 1967. His student, Shafer, further improved and promoted it. Thus, Evidence Theory is also called D-S Theory. Through improvement and development, D-S Theory has become a valid method to express and handle the uncertain information. Currently, it has achieved wide applications in the field of data integration and so on. It is mainly used to solve problems related to expert judgment, intelligent decision-making, talent assessment and risk assessment (Huang , 2007).

4.2 The evaluation method in this paper

Based on the above analysis and the author's knowledge level, this paper adopted the methods of The Fuzzy Comprehensive Evaluation Method.

Using the traditional fuzzy comprehensive evaluation method to evaluate the unit, the process is divided into four steps (Zhang, 2011, pp.46-49).

The first step: determining factor set and the evaluation set.

Suppose: U=(u_1 u_2 …u_m) on be behalf of comprehensive evaluation of many components set, called the factor set.

Suppose: V=(v_1 v_2 …v_n)is a variety of judgments constitute collection, called the evaluation set or comment set.

The second step: determine the weight of evaluation index vector.

Assume that A =(a_1 a_2 …a_m)as the evaluation index weight vector, Where as represents the factor's weights , and satisfy $\sum_{i=1}^{n} r_{ij} = 1, i = 1, 2, ..., m$ .In general, the factors on the evaluation factors are things effect is not consistent, so the factors weight distribution of A is a fuzzy vector.

The third step: Constructing fuzzy relation matrix.

In order to get the fuzzy relation matrix from U to V , often using the Delphi method. Firstly using the random sampling method from a composition comprising several with the evaluation factors related to various representatives to participate in the comparison group; then

making questionnaires to rating to each member of the group independently of factor concentrate every factors according to the reviews focused reviews of grade in evaluation, some factors that belong to a class will vote; the final statistical factors at each evaluation class recognized votes, the votes and the total number of votes compared to factor in a grade of membership.

Suppose rij represents factor i relative to the j reviews the grade of membership, R_i=(r_{i1} r_{i2} …r_{in}) represents the fuzzy evaluation vector of factor i , where

$\sum_{i=1}^{n} a_i = 1$,i = 1,2,…,m.

Then the fuzzy relation matrix for evaluation is

$$R = \begin{pmatrix} R_1 \\ R_2 \\ \vdots \\ R_m \end{pmatrix} = \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{pmatrix} .$$

The fourth step: Fuzzy comprehensive evaluation.

Suppose B is the evaluation results, and

B=A·R=(b_1 b_2…b_n)

Where b_j indicats the importance of the j factor in the overall V. If b=max(b_1 b_2…b_n), then the evaluation results for the things to make evaluation of b(maximum membership principle).

4.3 Risk identification

Putou branch waterway of Meizhou Bay Port starts from the Point G of the main waterway of Meizhou Bay to Point J′ of the end of Putou 4# berth, goes through 7# and 10#, the turning basin of liquid-cargo quayside which is planned by Xiuyu operating region. The nearest distance between the construction region and the nearby Xiao-Cuo oil wharf is 1300m, the shortest distance to one hundred thousand-level LNG wharf of Xiuyu operating region is 2200m, and it is 475m from the nearest Xiuyu general wharf, and 395m from the shortest frontier inspection wharf, 310m from Xiushan Mountain and 8# liquid-cargo wharf, about 700m from Putou 1# wharf, and the shortest distance from LNG pipeline is 285m.

During construction, the technological mean of reef explosion would be used. The explosion would impact the circumjacent ships, people and buildings within 1000m; in the process of dredging and reef cleaning operating, part of waterway would be occupied, and there would be risks to the transportation safety which goes through the construction water area, the risks of this engineering are mainly reflected in the following several aspects:

(1)Putou branch waterway is located near busy main waterway of Meizhou Bay. There are high risks and value targets of LNG submarine pipeline, oil wharf, LNG wharf and so on existing around. Once major safety accidents happen, it may have great influence on normal production operation of the whole Meizhou Bay Port;

(2) The long engineering construction time, large amounts of construction ships and occupation of waterway by dredge boats will bring risks on marine traffic in this sea area.

(3) There are fishery activities of marine aquaculture and so on near construction water area, fishing gear and fishing net may float to the construction water area, which will bring risks to the passing ships and construction ships;

(4) Construction ships and ships around wharf will increase traffic flow in the

surrounding water area, which increases difficulties of navigation management;
(5) Engineering reef explosion area and dredged area are close to LNG submarine pipeline of Meizhou Bay. The shortest distance of reef explosion area and submarine pipeline is about 125m. So the construction in this engineering may have some risks on safety production of pipelines. But according to the underwater detection result of LNG pipeline in the early stage, it can be found that cause of sedimentation erosion in the bottom of LNG pipeline and so on will lead to partial hanging of LNG pipeline and exposed to seabed surface, which increases construction risks.
(6) With the perfection of Meizhou Bay waterway conditions, expansion of each port area and more and more large-tonnage ships in Meizhou Bay, there are risks of insufficient anchorage grounds and emergency resource construction support;
(7) With the construction of this engineering, Meizhou Bay waterway would be expanded and improved, but with waterway cross and increasing of ship flow in the future, the probability of ship collision in this water area would also increase;
(8) Risks of accidents of pollution, fire, explosion and so on of ships;
(9) Risks of accidents of collision, grounding, machine failure and so on of ships in typhoon and other heavy weather.

4.4 Risk evaluation

4.4.1 Risk factor

In view of the fact that this engineering construction method is relatively mature and author's knowledge structure, ability level are limited,This paper does not use Analytic Hierarchy Process which could analysis the risk factor more clearly from human factor,machine faul,natural environment, management level and their sub-hierarchy.Instead of this,this paper adopted the System Analysis Method to analysis some more important factors based on the analysis of the engineering actual situation. According to Risk identification in the engineering, risk factors which affect ship navigation safety of this engineering could be concluded as follows(See Figure 3):

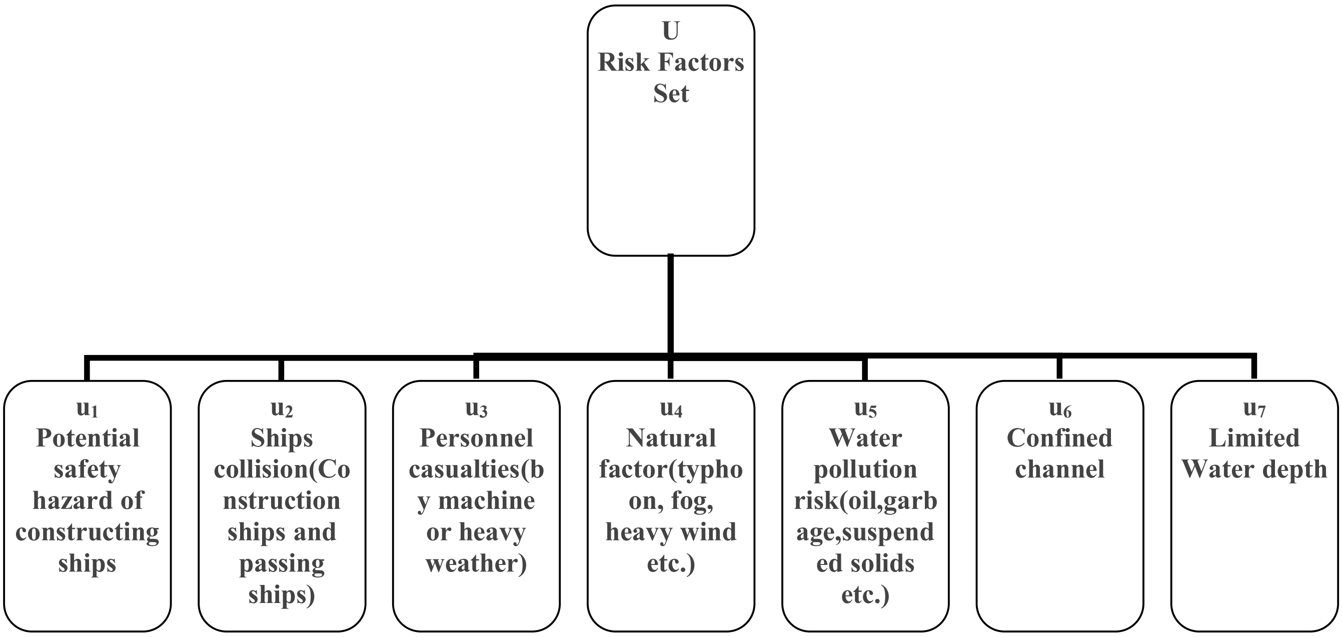

Figure.3 - Risk Factors Set

4.4.2 Risk qualitative evaluation

According to theory of engineering risk analysis, risk evaluation in engineering construction usually uses semi-quantity or qualitative risk analysis and evaluation (Bao, 2014). To this engineering ,we believe that the frequency of risk factors divided into 5 levels are reasonable. The rating is concluded as follows(See Table.1):

Table.1 - Qualitative risk probability level table

Frequency	Rating	Adjectival Description	The possible for

			happening
Often	A	May occur frequently	Continuing happened
Possible	B	Happened many times during the period of engineering construction	Often happened
Occasional	C	May be a few times during the engineering construction	Sometime happened
Rare	D	May occur during the engineering construction	Rarely happens
Negligible	E	Almost does not occur during the engineering construction	Theoretically possible

According to Table.1, it is believed that factors which happen more frequently have more affects on ship navigation safety.Combined with previous data and survey of engineering personnel the danger probability ratings of these engineering risk factors are shown in Table.2.

Table.2 - Rating table of Hazard Probability for Construction Risk Factors

Code	Risk Factors	Rating of Hazard Probability
u_1	Natural factor (typhoon, fog, heavy wind etc.)	D
u_2	Potential safety hazard of constructing	C
u_3	Water pollution risk	C
u_4	Ships collision	D
u_5	Personnel casualties caused by heavy weather	D
u_6	Confined waterway	C
u_7	Limited Water depth	C

It could be known from the above table that there is one C hazard probability rating, four D hazard probability ratings and two E hazard probability ratings.

4.4.3 Risk quantitative evaluation

When making marine traffic quantitative evaluation, fuzzy comprehensive judgment method is usually used for evaluation.

(1) Fuzzy comprehensive evaluation risk factor set of this engineering,

$U= \{u_1, u_2, u_3, u_4, u_5, u_6, u_7\}$

(2) The establishment of evaluation set of comprehensive judgment

The target of comprehensive judgment is to evaluate influence degree of each factor on ship navigation safety, so evaluation set is:

v={very large influence, large influence, general influence, small influence, nearly no influence}

(3) Evaluation matrix R is got by single risk factor fuzzy judgment

Corresponding to risk probability rating to get related evaluation set(See Table.3).

Table.3 -Risk probability rating corresponding table

Rating	Very large influence	Large influence	General influence	Small influence	Nearly no influence
A	0.8~0.7	0.2~0.1	0.1~0.0	0.0	0.0
B	0.2~0.1	0.8~0.7	0.1~0.0	0.0	0.0
C	0.1~0.0	0.2~0.1	0.8~0.7	0.0	0.0
D	0.0	0.0	0.2~0.1	0.8~0.7	0.1~0.0
E	0.0	0.0	0.1~0.0	0.2~0.1	0.8~0.7

Combined with navigation obstruction analysis and the featurs of risk factors in Chapter

3,this paper took the value in single factor(See Table.4).

Table.4 - Single factor evaluation set of this engineering

Risk factor	Rating	Evaluation set
u_1	D	R1={0.0,0.0,0.2,0,7,0.1}
u_2	C	R2={0.1,0.2,0.7,0.0.0.0}
u_3	C	R3={0.1,0.2,0.7,0.0,0.0}
u_4	D	R4={0.0,0.0,0.2,0.7,0.1}
u_5	D	R5={0.0,0.0,0.2,0.7.0.1}
u_6	C	R6={0.0,0.2,0.8,0.0,0.0}
u_7	C	R7={0.0,0.2,0.8,0.0,0.0}

(4). Making comprehensive judgment according to the judgment model

This evaluation is made on influence degree of ship navigation safety.Through the survey of from the senior captain, maritime safety administration, and engineering management personnel, according to results in qualitative evaluation and comprehensive consideration of all aspects in this engineering from probability,influence and emergency resource of each factor, the weight of each risk factor can be determined as follows:

A=(0.10,0.20,0.15,0.15,0.10,0.15,0.15),

so the evaluation model is:

B=A·R=(0.04,0.13,0.55,0.24,0.04).

(5) Evaluation results

Table.5 - Risk evaluation result of this engineering

Evaluation set	Very large influence	Large influence	General influence	Small influence	Nearly no influence

Results	0.04	0.13	0.55	0.24	0.04

Risk evaluation results could be got in Table 4-5, after comprehensive judgment of influence of each risk factor on ship navigation safety, the total proportion of "very large influence" and "large influence" is about 17%, the relative risk value is normal.

4.5 Chapter Summary

This chapter first introduces the theory and common methods of navigation safety evaluation, which includes Safety Index Assessment method, grey system theory , fuzzy evaluation method, analytic hierarchy process, comprehensive safety evaluation, probability risk assessment method ,artificial neural network evaluation method, data envelopment analysis method and evidence theory. However, based on the practical situation of the engineering, the author uses the fuzzy comprehensive evaluation method in this paper. The fuzzy comprehensive evaluation method is widely used in navigation safety evaluation at present, so the method is reviewed in detail: through determining factor set and the evaluation set, determine the weight of evaluation index vector, constructing fuzzy relation matrix, and fuzzy comprehensive evaluation four aspects. The author analyzes the risk factors of this engineering, and determines the parameters and the weight of each factor through experts investigation, finally used the fuzzy comprehensive evaluation method to calculate the risk evaluation result of this engineering. The resulting conclusion is that the relative risk value is normal.

CHARPTER 5 SOME SUGGESTIONSON REDUCING RISKS

5.1 Reasonable organization of marine traffic

For ensuring safety operation of The Putou Operational area during construction of 70,000 DWT waterways, two-side construction method is suggested when making seabed punching, rock cleaning and dredging, in order to leave half width of waterway for passing of ships. The width of construction section of 7 tons level waterway is 200m, according to calculation of leeway and drift angle of 7°, the single-direction waterway width which is needed by navigation of 1 ton level ships is 100m, so half width of waterway could satisfy single-direction passing requirement of 1 ton level ships. So ground tackle of construction ship would partly stretch into waterway range of navigation side during construction period, which would constitute navigation obstruct influence on passing ships, so on one hand, the anchor in waterway side should be thrown in position with large depth of water, on the other hand, construction ships should stop construction when there are ships passing through, and loose anchor chain in navigation side suitably to eliminate navigation obstruct influence(Zhao G., 2010).

The warning scope exceeds navigation scope when making reef explosion in Putou 70,000 DWT level waterway, it needs to take measures to keep passing ships far away. It should apply to maritime sector for release navigation warnings to forbid ships from entering warning scope. Blasting operation needs to choose time sections without passing of ships, outlook should be enhanced when making reef explosion, and sending guard-ship to cruise around, warning timely when finding ships nearby to avoid ships entering warning scope, the explosion time is short, and warnings can be relieved after explosion is completed.

The following points should be noticed when organizing construction ships traffic: 1. Stone dumper should sail to the specified location along current waterway when transportation; mud dumper should notice nearby small fishing boats when sailing; cargo ship would enter port with tide when rising tide, ship flow and sail-direction should be specially paid attention to, avoiding operation should be made according to International Regulations for Preventing Collisions at Sea as early as possible when there are ships passing through the construction water area.

5.2 Special protection of LNG submarine pipeline

The construction of dredging and reef explosion may lead to changes of hydrodynamic force and sediment hydrodynamic force, which enlarges hanging problem of LNG submarine pipeline and scours seabed near LNG submarine pipeline and causes submarine landslide. Constructors should make exploration on seabed near LNG submarine pipeline discontinuously during construction period and further argumentation. The laying situations of LNG submarine pipelines in working sea area should be investigated clearly before construction, and explaining to all constructors, making protection plans and measures for current submarine pipelines to avoid damaging current submarine pipelines during construction. The protection plan should request permission of pipelines owner –Fujian Natural Gas Co., Ltd (CNOOC) and related departments. Main ships of dredger and so on are forbidden to drop anchor in submarine pipelines area during the construction process. The coordination of location of submarine pipelines should be determined before construction, construction ships control anchor positioning of ships by GPS location to ensure that there are enough safety distances between ship anchor area and submarine pipelines. If ship anchor grapples submarine pipelines when operation and causing shifting or damage of submarine pipelines, it should report to Putian MSA and submarine pipeline owner –China National Offshore Oil Corporation (CNOOC) Fujian Natural Gas Co., Ltd. Explosive dosage should be controlled when making reef explosion, and monitoring vibration velocity of LNG pipelines in real-time. The vibration velocity of pipelines can't exceed allowed value. In addition, backfill disposition should be made in time when prospected to find that submarine pipeline is exposed out of seabed.

5.3 Setting warning area in reef explosion period

For ensuring construction safety in reef explosion, construction unit should apply to make sailing announcement (warning) before implementing reef explosion and set warning zone, swimming and diving operation is forbidden within 1000m scope of explosion zone during explosion period, because the distance requirement of safety passing of ships when

5.4 Adjusting the Navigation Marks during the Mud-dredging and Reef Explosion

Owing to the fact that Putou operational area s still in operation during the construction period, there are entry and departure of vessels. In order to guarantee the basic navigation conditions, the construction will adopt the plans that make possible the construction on one side while navigating on the other side. To lead the vessels navigate along one side of available navigable waterways during the construction period, it shall properly adjust the current navigation marks within the construction area, which includes those marks, such as # 703 (starboard buoy), # 704 (port buoy) and # 706 (port buoy) etc. Namely, when the construction vessels are on the port side of the navigation waterway, such port buoys as # 704 and # 706 shall be removed to the central-line of navigation waterway to guarantee the smooth navigation of starboard side. On the contrary, when the construction vessels are on the starboard side of the navigation waterway, such starboard navigation buoys as # 703 shall be removed to near to the central-line of the navigation waterway to guarantee the smooth navigation of port side. The adjustment of navigation buoy shall be carried out by the competent authorities.

5.5 Guarding against the Unexpected Explosion Accidents

The blasting work shall be administered in a unified manner. The blasting engineers are responsible for the blasting design based on the parts of engineering and full-time blasting safety supervisors shall supervise the whole process of explosion. All relevant personnel involved in the explosion work shall go through the trainings of Public Security Departments, then pass the examinations and obtain the certificates before they can engage in the explosion work. The explosion shall be carried out in strict accordance with the blasting design in order to guarantee the safety and achieve the desired results. The full-time blasting safety supervisors shall be set up in the blasting work to supervise the whole process of blasting and strengthen the control and supervision of whole depth, explosives payload, warning and detonation. It can be detonated only when the detonation process has been inspected and agreed by the safety supervisors. The warning area shall be set up around the blasting area, which shall timely be reported to the VTS command centre. Before the explosion, it shall raise the alarm and keep all the personnel and equipment within the safety distance as required and the warning area has been set up and it can be detonated after the inspection and confirmation of the blasting safety supervisors. Besides, it shall record the process of blasting, including such things as time, place, explosive payload, explosive materials, parameters of the blasting holes etc. The detonation shall never be carried out in foggy days, thundery days, twilight and evening.

5.6 Establishing safety management system for construction engineering

All of ships that participate in the construction engineering should carry all necessary certificates which issued by the MSA or the classification society. Crew on board should have relevant certificates which correspond to their posts. Ships and the crew on board will be supervised and inspected by the MSA and other administrative department.

Ships under dredging construction are supposed to display the specified signal lights all day in observable places according to relevant regulations. According to the requirements set by MSA, construction ships are supposed to make an area of safe operation or caution area and set relevant signals according to provisions.

During the process of construction, the constructing ships should strictly obey the international regulations for preventing collisions at sea and other relevant regulations and requirements. Those ships are equipped with effective communication facilities. Crew on the ships should watch on VHF and communicate with the passing ships actively, informing other ships with the construction and sailing trend and ensuring the navigation safety. Crew on constructing ships should strictly obey the operating instruction for safety technology and forbid the violate commanding, violate operation and violate labor discipline (Lei, 2006)..

The constructing ships should make pre-arranged planning for typhoon-prevention, flooding-preventing, fire-prevention and heatstroke-prevention according to the actual condition of the working area as well as the seasonal change, and then send to higher level security department for approval. The staffs involved in over-water construction should wear life jacket and should never work after drinking. The constructing ships should have inspection to the safety production condition at fixed period, and give quick response to the potential risk, and then record into security activity.

It should set up security management system for blasting work and work according to the safety technological program strictly. The blasting staff should have relative certificates. They have to work according to the blasting design program. The site technical personnel make analysis of the chance factor and then come up with safety blasting index. If the measured data are bigger than the allowable value, none is supposed to work and should make quick adjustment.

It should set up blasting security alert system. People should be alert before the blasting and make sure that there's no ship or people in safety distance. Alert can be cleared after checking of inspectors.

5.7 Relevant contingency plan should be set

During the constructing process, there is emergency situation like staff falling into water, ships collision, and fire hazard. Thus relevant departments should make relevant contingency plan to cope with various emergency accident as well as the emergency arrangement. It has to make sure of relevant responsible departments and staff as well as the disaster preparedness exercise system to improve the reaction capacity under the emergency situation and give quick response to various accidents and emergency situations. Once a relevant accident or emergency happen, on the one hand, it should give alert as soon as possible and report to the party concerned; on the other hand, the party concerned should start emergency actions immediately and cooperate actively, organize and cooperate with efficiency. According to the real situation, all the effective measures and equipment should be utilized to control the situation and rescue lives with the purpose to solve the emergency as soon as possible and reduce the lose and influences caused by the accident.

These contingency plans should include but not limit to: the emergency disposal plan for people falling into water; emergency disposal plan for ships collision; contingency plan for fire hazard and blasting; contingency plan for ships pollution accidents; pre-arranged plan for hurricane and typhoon- prevention.

CHARPTER 6 CONCLUSION

The construction scheme of Putou Branch Waterway Extension Engineering conforms to the requirements of the general plan for the engineering of navigation waterway in Meizhou Bay. The branch waterways can meet the needs of ship in and out of Putou Port Area. The construction of this engineering is necessary and urgent.

According to the general plans for the phrase III engineering of navigation waterway in Meizhou Bay and the construction plan of Putou branch waterway extension engineering, this paper analyzes the navigation environment , navigation obstruction and the interplay between the engineering and the environments of nature and navigation. Through comparing the common methods of navigation safety evaluation, based on the practical situation of this engineering the author uses the fuzzy comprehensive evaluation method to calculate the risk evaluation result of this engineering. The resulting conclusion is that the relative risk value is normal. Finally, the author puts forward some reasonable suggestions to reduce the potential risk in this engineering construction. However,this paper does not use the analytic hierarchy process to analyze risk factors from probability,influence and emergency resource. This should be noted ,because it may have a certain influence on the evaluation results.

In conclusion, based on the reasonable construction scheme and necessary security measures， the navigation safety risk of Putou branch waterway extension engineering can be controlled to a relatively low level, which can be accepted by the society.

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