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Research on navigation guarantee measures of modified Dan'gan waterway routeing system

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WORLD MARITIME UNIVERSITY

Dalian, China

RESEARCH ON NAVIGATION GUARANTEE MEASURES OF MODIFIED DAN'GAN WATERWAY ROUTEING SYSTEM

By

CHANG PENG

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MANAGEMENT

2016

DECLARATION

I certify that all the material in this research paper that is 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

Title of Research Paper: **Research on Navigation Guarantee Measures of Modified Dan’gan Waterway Routeing System**

Degree: **MSc**

This research paper is a study of how to design an aid to navigation system in a particular ship routeing system.

An overview of ships routeing system in China is examined for the purpose of introducing navigation guarantee measures, and the basic situation, natural conditions, traffic flow and quantitative description are scrutinized to lead the subsequent focused discussions on the point of view which setting the lightvessel is necessary and feasible.

The establishment of a lightvessel is a complicated issue, and the achievement may be various kinds. This paper designs the lightvessel from AtoN requirements, AtoN power, RNav-Racons, AIS and AtoN maintenance these different aspects, in order to illustrate the necessary navigation guarantee measure in a routeing system.

After the establishment, a cost-benefit assessment is needed to check whether the lightvessel is proper or not. The conclusions are addressed on the basis of suggestions and problems of this research paper that the lightvessel is a promotion to the maritime safe of Dan’gan Routeing system. But there are also some problems that this paper didn’t solve, such as the detailed design of the lightvessel.

KEY WORDS: lightvessel, routeing system, hierarchy evaluation, risk assessment

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LIST OF ABBREVIATIONS

AIS	Automatic Identification System
AHP	Analytic Hierarchy Process
AtoN	Aids to Navigation
CCTV	Closed Circuit Television
DC	Direct Current
GCRS	Guangzhou Coast Radio Station
GPS	Global Positioning System
HKSAR	Hong Kong Special Administrative Region
HKVTC	Hong Kong Vessel Traffic Center
HSC	High Speed Craft
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IMO	International Maritime Organization
LED	Lights Emitting Diode
LNB	Large Automatic Navigation Buoy
MOC	Ministry of Communication
MOT	Ministry of Transportation
MSA	Maritime Safety Administration
MTBF	Meantime-between-failure
MTTR	Meantime-to-repair
NGCS	Navigation Guarantee Center of South China Sea
SOLAS	The International Convention for the Safety of Life at Sea
VTS	Vessel Traffic Services

Chapter 1

Introduction

Over the years, IMO has put in place several measures with the twin objectives of enhancing the safety of navigation and protecting the marine environment. For instance, set aids to navigation, pilotage as an aid to navigation, routeing and nautical publications.

1.1 Purpose of ships' routeing system

The General Provisions about Ships' Routeing are formulated based on regulation v/8 of the SOLAS Convention. The purpose of ships' routeing system is to improve the safety of navigation in converging areas and in areas where the density of traffic is great or where freedom of movement of shipping is inhibited by restricted sea-room, the existence of obstructions to navigation, limited depths or unfavorable meteorological conditions. Ships' routeing may also be used for the purpose of preventing or reducing the risk of pollution or other damage to the marine environment caused by ships colliding, grounding or anchoring in or near environmentally sensitive areas. (IMO, 2003)

The following terms are used in connection with matters related to ships' routeing system: routeing system, mandatory routeing system, traffic separation scheme, separation zone or line, traffic lane, roundabout, inshore traffic zone, two-way route, recommended route, recommended track, deep-water route, precautionary area, area to be avoided, no anchoring area, established direction of traffic flow and recommended direction of traffic flow.

When planning, establishing, reviewing or adjusting a routing system, the following navigational guarantee factors should be among those taken into account by a Government: 1) the adequacy of existing navigational marks, nautical charts, and hydrographic surveys of the area; 2) environmental factors such as prevailing weather conditions, currents and tidal streams; 3) whether there might be hazard to an aid to navigation; and 4) if there is doubt as to the ability of ships to fix their positions positively and without ambiguity in relation to separation zones, serious consideration should be given to provide adequate marking by buoys or light marks. (IMO, 2003)

1.2 Navigation guarantee measures

There are 3 kinds of navigational guarantee measures in today's maritime safety, namely Aids to Navigation, Hydrography and Telecommunication (coast radio station). The Dan'gan Waterway has already had specific hydrographical materials and in the range of Guangzhou Coast Radio Station (GCRS), ships which are navigating nearby can refer to the chart and receive the maritime safety information. Aid to Navigation, which is another important measure of navigation guarantee in this area is very weak.

A marine Aid to Navigation (AtoN) is a device or system external to vessels that is designed and operated to enhance the safety and efficient navigation of vessels or vessel traffic. The coverage areas of aids to navigation of varying complexity (including lights, sector lights , leading lights and racons) is a very important measure to provide the accurate position of ships. (Wang, 1997)

1.3 The status of navigation guarantee measures of some typical routeing system in China

Here are some typical routeing systems in china, from what we can find some navigation guarantee measures such as the major floating aids. There are two lightvessels named Changjiangkou and Nancao in the Yangtze estuary ships routing system, we have Guishanbei lightvessel in Dahao Routeing system of Pearl River Estuary. See figure 1.1.

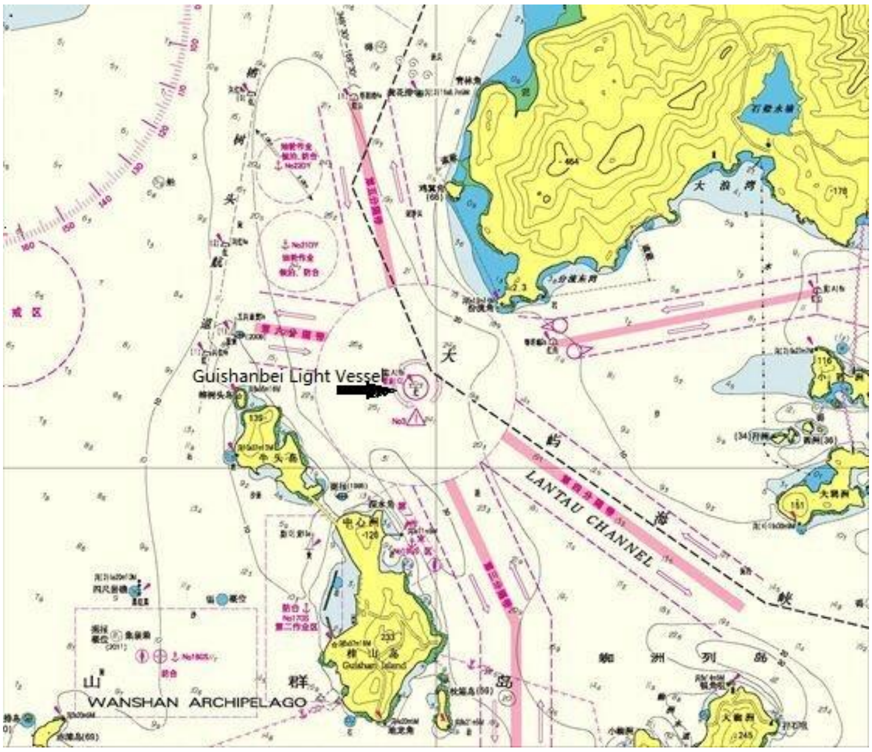

Figure 1.1 –Dahao Routeing system of Pearl River Estuary

Source: Route atlas of Pearl River Estuary

In accordance to "IALA NAVGUIDE", Lightvessels, lightfloats and lanbys (or LNB) are defined as major floating aids and may carry a racon, sound signal, and in some cases, a radio beacon in addition to the aids to navigation light. A lightvessel may also display a white riding light to signify a vessel at anchor (IALA-AISM, 2006). So a lightvessel may be needed in the modified Dan'gan Waterway Routeing System.

Chapter 2

The reason of changes in Dan’gan Waterway shipping routeing system, and the evaluation of the modified system

2.1 The try out system

In June 1, 2004, the China MOC (Ministry of Communication) issued and implemented “The Ships Routeing System of the Pearl River Estuary (try out)” and “The Ships Report system of the Pearl River Estuary (try out)”. Pearl River Estuary is the routeing system which consists of Dan’gan Waterway Routeing System and Dahao Waterway Routeing System. Dan’gan Waterway Routeing System is taken stick by 2 traffic separation areas and of two precautionary areas, and connects with the Hong Kong East Lamma Waterway traffic separation scheme.

After established, the Dan’gan Waterway routeing system has played a very important role to protect the waters of the ship navigational safety and pollution prevention, but with the great increasing of vessel density in this area, several major accidents occurred here. Through research and analysis, the uncertainty of exports south sailing ship from Hong Kong east Lamma waterway is the most important reason.

2.2 The environment and traffic condition of Dan’gan Waterway

Dan'gan Waterway is the main channel for the eastern route, waters around the islands and the anchorages, there are many different kinds of passing ships and the traffic flow density is heavy, plus to the traffic flow freely crisscross, route complex, and ships steering and intersection here from Hong Kong, Shenzhen, Guangzhou, Zhuhai and other places, more ships navigational safety are faced with great threaten. So when ships sailing east through the second precautionary area in Dan'gan Waterway, there is a greater risk of navigation. Since the implementation of routing system, Ship accident rates fell a little, but as the traffic tonnage enlarged, the ship speed increased, the collision risk still seems obvious.

Here take two of the main casualties in this area for example. On May 21st, 2010, Container ship "Chief" from Shenzhen Chiwan port via Hong Kong to Mexico on the way, in the second precautionary area of Dan'gan Waterway routeing system collided with ship "Changfakou", caused ships damaged and 1 container drown accidents; On April 7th, 2012, after ship "PAPHOS" turned to the right in the second precautionary area of Dan'gan Waterway Routeing, the port bow had collided with "China shipping high speed", lead to two ships' hull damage. (Guo & Fan, 2014)

Two casualties occurred in good visibility, sailing under the good sea condition. Analysis shows the cause of the casualties, mainly is the uncertainty of the ship heading when in and out Hong Kong east Lamma waterway, unfavorable to the ships collision avoidance in the intersection of second precautionary area of Dan'gan Waterway, so this is the environmental factors of collision accidents.

2.3 The modified system

On July 1st, 2015, China MOT implemented the new ships routing system of the Pearl River Estuary for the adjustment. There are some differences. Firstly, the traffic lane is moved a little southward to reduce the overlap with the Hong Kong waters; secondly, settings recommended by vessel traffic flow direction in the second precautionary area to reduce the number of traffic flow, which is convenient for ship collision avoidance.

After the 2015 revision, Dan’gan Waterway traffic separation scheme do not overlap with the Hong Kong waters; expanded the width and length of traffic lane, fine-tuning the mainstream of ships, increased the first and second traffic lane width from 0.5 nm to 0.6 nm, increased about 1 nm in length, and recommend the traffic flow direction. See Figure 2.1.

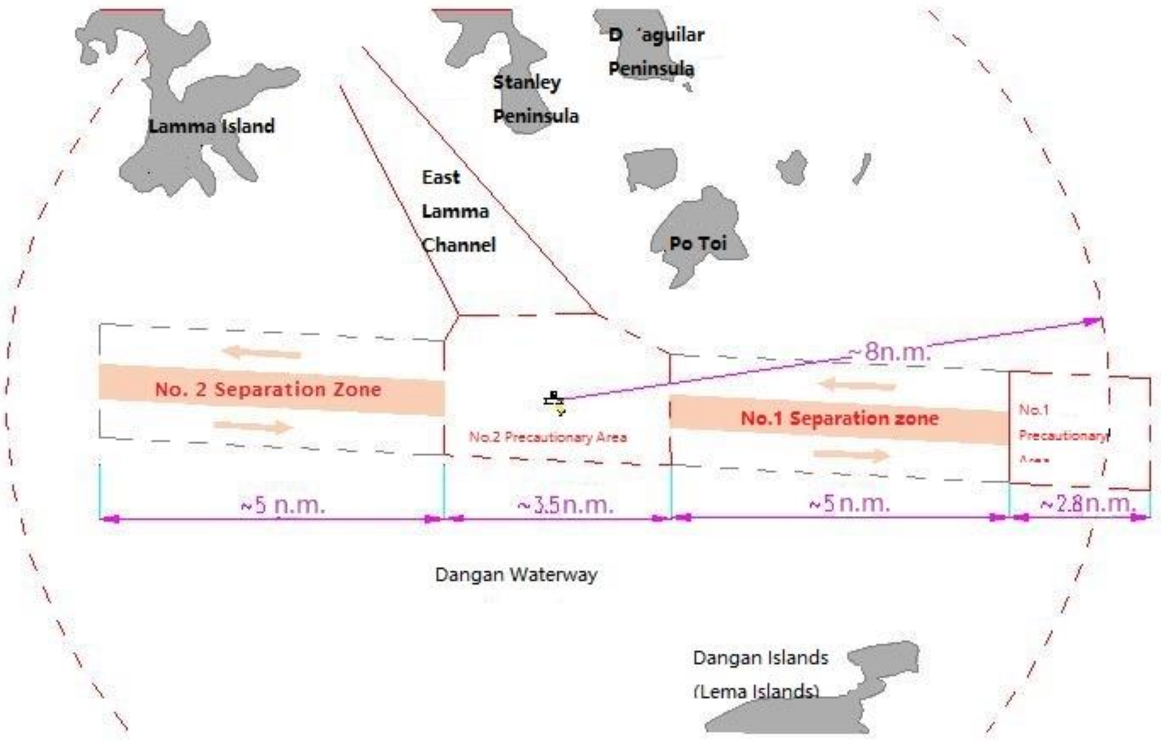

Figure 2.1- Sketch map of Dan’gan Waterway routeing system

So the designed lightvessel will be set in the second precautionary area, the exact position is

22°07′36.3”N; 114°13′32.2”E.

2.4 Basic situation of Dan’gan Waterway

The major waterways in Pearl River Estuary are Dan’gan Waterway, Dahao waterway, Dadanwei channel, Onishi channel, Lingding Fairway and other artificial dredging channels, etc. Dan’gan Waterway located between Dan’gan Island and Po Toi Island. There is no other obstruction in Dan’gan Waterways except sunken ships about 1.4 and 3.6 nautical miles northeast to Dan’gan Island, easy for navigation. To the north of Dan’gan Waterway there is the Lamma anchorage of dangerous goods, many ships refuel and transship there; to the south of Dan’gan Waterway, there are anchorages for ultra large container vessels and typhoon anchorages. (GD MSA, 2015)

2.4.1 The main traffic flow of Dan’gan Waterway

Dan’gan Waterway is located in the east traffic arteries of Pearl River Estuary. The east traffic flow of Pearl River Estuary is mainly ships to and from Qinhuangdao, Tianjin, Dalian, Qingdao, Shanghai, Jiangsu and Zhejiang, Fujian, Guangdong and other domestic routes ship flow, as well as international routes through the Taiwan strait and the Bashi channel, Balintang strait, such as flow of ships to and from Japan, the Korean Peninsula, the Far East, Asia Pacific, Europe, North America. In addition, the Pearl River Estuary is one of the most frequent areas where high-speed passenger ships navigating, high-speed passenger ship sailing round-trip mainly in Guangdong, Hong Kong and Macau. (Li, 2015) See Figure 2.2.

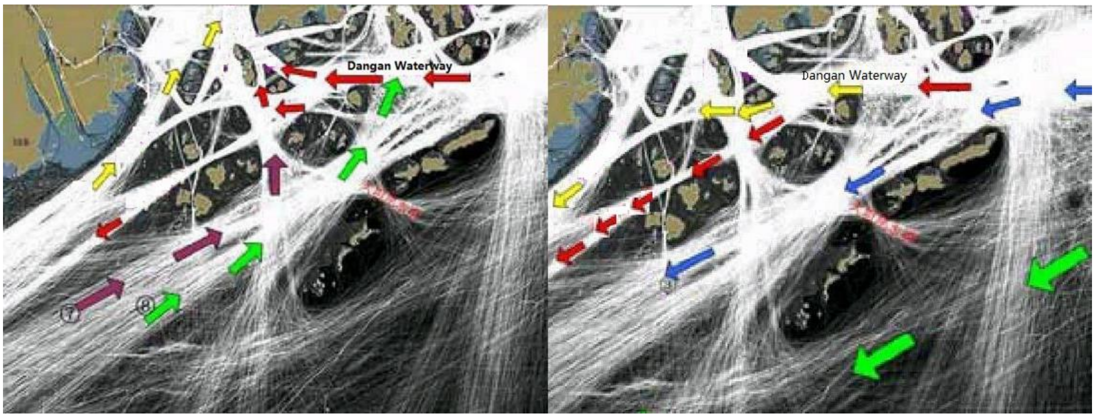

Figure 2.2 – Main traffic flow of Dan’gan Waterway (2010.3)

Source: Sheng Xingxing (2014). *Research on Revising the Ship Routeing System of the Pearl River Estuary*. Pearl River Water Transport

Because the injection of the Pearl River brings a wealth of bait, Wanshan islands waters which near Pearl River Estuary, has been made an important fishing ground off the coast of Southern China (Sheng, 2014). On catching season, a large number of fishing boats catch fish in Dan’gan Waterway, Dahao waterways and Onishi waterway, the varied types and operation way of fishing boats made the traffic flow more complex.

After the extensive domestic and international routes flow convergence in the eastern Dan’gan Waterway, diversion by the western Dan’gan Waterway to each port of the Pearl River Estuary and Hong Kong's Victoria Harbour, formed a dense east direction vessel traffic flow.

2.4.2 Shipping economic development in Pearl River Estuary

Pearl River Estuary is one of the most advanced shipping waters in China; big cities such as Hong Kong, Guangzhou, Shenzhen, Zhuhai, Dongguan, Zhongshan, and Macao are distributed on both sides of it. There are many important ports and docks. Huge urban agglomerations generate great logistics transport demand. The main Pearl

River Delta cities' economy accounts for 85.3% of Guangdong economic aggregate, accounted for 7.6% of the whole country.

Shipping is the main mode of transportation in international trade. Shipping has the characteristics of the large volume, low freight rate per unit, especially the import and export transportation of raw materials, oil and bulk commodities can only rely on shipping, shipping plays a very important role in the import and export trade. (Stopford, 2009) The Pearl River Delta is now the world's largest export processing zone and the world manufacturing base and international procurement center, has great potential for development in shipping logistics demand.

The Pearl River Delta has 23 main navigable waterways, Hong Kong, Shenzhen, Guangzhou three big ports which have natural deep water conditions, together with other small and medium-sized ports, formed a large comprehensive port group of Pearl River Estuary, with good water conditions, natural harbors and the intensive international routes (The National Development and Reform Commission, 2008)

Chapter 3

Discuss the rationality and scientific nature of navigation guarantee requirements with the fuzzy synthesis judgment methodology

3.1 The Aids to Navigation status in Dan’gan Waterway

At present, the China mainland beacon administration does not have special Aids to navigations (AtoNs) in Dan’gan waters. Ships navigation in this waters mainiy reference the islands around, landmark buildings, and Hong Kong AtoNs and charts.

Ships from the east entre into Dan’gan Waterway mainly refer to the position of Dan’gantou, and it is situated at the eastern extremity of the Dan’gan Island, the typhoon signal station in Dan’gantou is 226 meters high, it is easy to identify. at the entrance of the east side of Dan’gan Waterway traffic lane, there has been a sunken ship named “Licheng” , the wreck was equipped with an isolated danger buoy, due to its special location, it was taken as an AtoN of the east into the north Dan’gan Waterway traffic lane in a period, after meeting the requirement of water depth, the buoy has been removed in 2013. Ships From the west into Hong Kong waters can obtain navigational service by contact with Hong Kong Vessel Traffic Center (HKVTC), contact sites are located in Putai Island, the channel 1 Lamma buoy and

Nanyapai buoy in East Lamma strait, the Qingzhou Island and the west quarantine anchorage, etc.

After the modify of the Dan’gan Waterway routeing system, if Lighthouse Authority set a lightvessel in the second precautionary area to recommend vessel traffic flow direction, it can mark the position of the precautionary area, warning ships to reduce human error and avoid collision, may have a great effect in enhancing navigational safety.

3.2 Traffic flow and the size of ships navigating through Dan’gan Waterway

When designing an AtoN system for an existing or a newly designed waterway, many considerations are necessary. From the discussion above, it is easy to find that maybe establishing a lightvessel in the second precautionary area is a good choice. In order to analysis the size of ships in and out of the waterway, the author selected the typical cross section, and uses the AIS management system to do the statistics. Temporal interval is 13:00 May 15, 2016 to 14:00 June 16, 2016.

3.2.1 Section analysis

Section 1: segment between 22°08′18.72"N/ 114°15′18.54"E and 22°06′36.18"N/ 114°15′18.54"E; this section is located in east side of the second precautionary area.

Section 2: segment between 22°08′54.42"N/ 114°15′09.54"E and 22°08′54.66"N/ 114°12′02.46"E; this section is located in north side of the second precautionary area. The sketch map is as Figure 3.1.

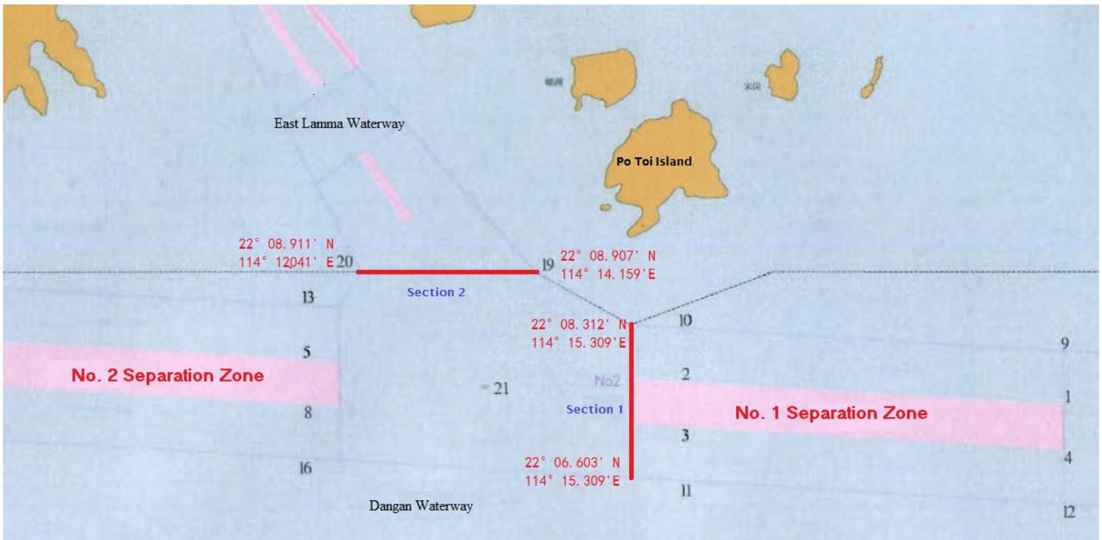

Figure 3.1 – Sketch map of traffic flow statistics section

Source: AIS management system

3.2.2 Courses and number of ships

In the range of interval statistics, the total ships and courses through the cross section are in the following Table 3.1.

Table 3.1 – Courses and number of ships (Unit: ships)

SECTION	COURSE 1	SHIPS	COURSE 2	SHIPS	TOTAL SHIPS
SECTION 1	E → W	1226	W → E	2917	4143
SECTION 2	S → N	1123	N → S	1663	2786

As per statistics, the ship's average daily traffic number through section 1 and section 2 is 130 ships and 87 ships respectively, the peak flow rate can reach 220 to 250 ships per day.

3.2.3 Size of ships

According to the information obtained from the statistics, ratio statistics of ship length segment are in the following table.

Table 3.2 – Ratio statistics of ship length segment

Size of ships	Section 1	Section 2
<50m	1.03%	0.26%
50-100m	21.52%	5.65%
100-150m	20.68%	19.60%
150-200m	25.35%	28.81%
200-250m	9.34%	12.26%
250-300m	13.63%	19.92%
>300m	8.45%	13.50%

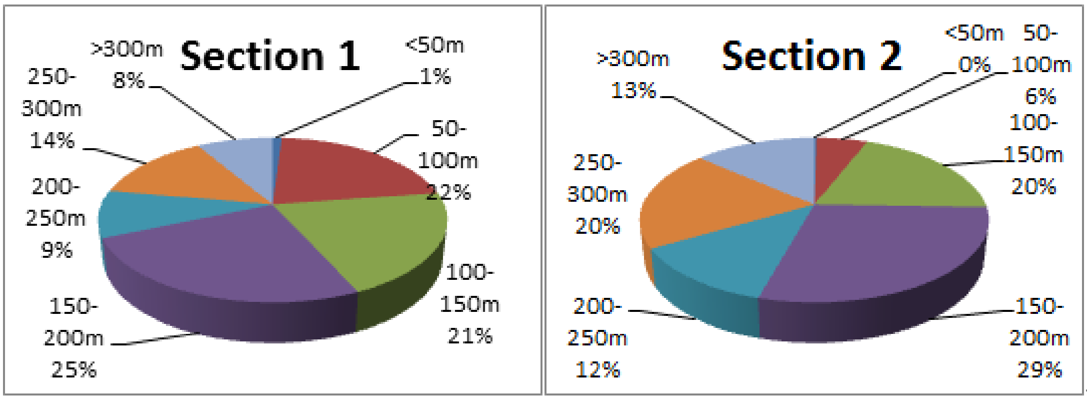

Figure 3.2 –Ship length distribution diagram

From the diagram above, it is easy to find that most of ships navigating through Dan’gan Waterway are large and medium-sized ships. The length greater than 100m of ships sailing through section 1 account for 77.45% of the total ships, while account for 94.09% of section 2.

Large ships with characteristic of higher eye-height, restricted by waterway waters, harder ship maneuvering performance, electronic navigation equipment fully equipped, etc. Corresponds to clear, large target and long light range aids to navigation equipped with diversification equipment such as Radar Beacon and AIS terminal. Be that as it may, buoys' efficiency cannot meet the requirements, which is a further evidence of the necessity of the construction of the lightvessel. (Yang & Liang, 2004)

The analysis of this research paper was done by using both quantitative and qualitative ways in consideration of provision Aids to Navigation rationality.

3.3 Evaluation of influence factors in setting aids to navigation

3.3.1 Indicative risk factors relating to marine navigation

How to prove Aids to Navigation rationality, what steps need to be taken to improve the navigation efficiency? The above questions are really depending on evaluation on the rationality of the fairway conditions. In the evaluation of the effects of multiple factors on the system, especially on the impact of various factors on the system information under the condition of insufficient or not clear, it is a good method by using the fuzzy comprehensive evaluation theory to do the research work. How to prove Aids to Navigation rationality is a fuzzy concept itself, and the influencing factors of evaluation objects is numerous, they have very strong fuzziness. A fuzzy evaluation associated with a range of factors that may affect the Aids to Navigation provision. See Table 3.3:

Table 3.3 – Indicative risk factors relating to marine navigation

Ship traffic consideration	**Traffic volume**	**Navigational conditions**	**Waterway configuration**	**Short-term consequence**	**Long- term consequence**
Quality of vessels	Deep draught	Night/Day operation	Depth	Injuries to people	Health and safety impacts
Crew competency	Shallow draught	Sea state	Channel width	Oil spill	Lifestyle disruptions
Traffic mix	Commercial fishing vessels	Wind consideration	Visibility obstructions	Hazardous material release	Fisheries impacts
Traffic density	Recreational boats	Currents (river, tidal, ocean)	Waterway complexity	Property damage	Endangered species
Nature of cargo	High speed craft	Visibility restrictions	Bottom type	Denial of use of waterway	Shoreline damage
		Ice conditions	Stability (siltation)		Reef damage
		Background lighting			Economic impacts
		debris			

Source: IALA Aids to Navigation Manual

3.3.2 Evaluation index system

Analysis of the factors affecting Aids to Navigation provision and the determination of evaluation index. On the basis of analyzing the waters, the factors which will influence Aids to Navigation provision are selected for hydrologic meteorological factors (nature conditions), channel conditions and traffic conditions. Hydro-meteorological factors including the visibility and wind, wave and current; Channel conditions including channel length, depth and curvature; Vessel traffic conditions including flow rate, type and scale of the ship. With the help of Delphi expert investigation method, determine the evaluation indexes for visibility, wind, wave and flow, channel length, channel depth, channel curvature, vessel traffic factors and channel width. (Huang, 2012)

Table 3.4 – Hierarchy evaluation model

U The evaluation index system of AtoN necessity
- U_1 Natural conditions
  - u_1 Visibility
  - u_2 Wind, wave and current
- U_2 Channel conditions
  - u_3 Channel length
  - u_4 Channel depth
  - u_5 Curvature of the channel
- U_3 Traffic conditions
  - u_6 Traffic factors + channel width

3.3.3 Problems solving steps of using the AHP (Analytic Hierarchy Process)

The AHP method is an effective way to calculate the weights; there are several steps in using the AHP method: Firstly, establish a hierarchy structure; secondly, construct a judgment matrix; then calculate weights by the judgment matrix; finally check the consistency of judgment matrix. (E.Bal Besikci, 2016)

Table 3.5 – Judgment matrix table

X/Y	Visibility	Wind, wave and current	Channel length	Channel depth	Curvature of the channel	Traffic factors +channel width
Visibility	1	1/3	4	6	3	1/4
Wind, wave and current	3	1	5	7	4	1/3
Channel length	1/4	1/5	1	3	1/2	1/6
Channel depth	1/6	1/7	1/3	1	1/4	1/8
Curvature of the channel	1/3	1/4	2	4	1	1/5
Traffic factors+ channel width	4	3	6	8	5	1

Source: Guo Jianguo (2000). *Synthesis evaluation of the placement of aids to navigation in port environment.* Dalian, China

Put the sub-indexes multiply, and then get the N-th root of the result u_i:

$$u_1 = \sqrt[6]{1 \times \frac{1}{3} \times 4 \times 6 \times 3 \times \frac{1}{4}} = 1.348$$

$$u_2 = \sqrt[6]{3 \times 1 \times 5 \times 7 \times 4 \times \frac{1}{3}} = 2.279$$

$$u_3 = \sqrt[6]{\frac{1}{4} \times \frac{1}{5} \times 1 \times 3 \times \frac{1}{2} \times \frac{1}{6}} = 0.482$$

$$u_4 = \sqrt[6]{\frac{1}{6} \times \frac{1}{7} \times \frac{1}{3} \times 1 \times \frac{1}{4} \times \frac{1}{8}} = 0.251$$

$$u_5 = \sqrt[6]{\frac{1}{3} \times \frac{1}{4} \times 2 \times 4 \times 1 \times \frac{1}{5}} = 0.715$$

$$u_6 = \sqrt[6]{4 \times 3 \times 6 \times 8 \times 5 \times 1} = 3.772$$

So the weight of each factor which affects the aids to navigation planning is as follows:

$$w_1 = \frac{u_1}{\sum_{i=1}^{n} u_i} = \frac{1.348}{8.847} = 0.152$$
$$w_2 = \frac{u_2}{\sum_{i=1}^{n} u_i} = \frac{2.279}{8.847} = 0.266$$
$$w_3 = \frac{u_3}{\sum_{i=1}^{n} u_i} = \frac{0.482}{8.847} = 0.054$$
$$w_4 = \frac{u_4}{\sum_{i=1}^{n} u_i} = \frac{0.251}{8.847} = 0.028$$
$$w_5 = \frac{u_5}{\sum_{i=1}^{n} u_i} = \frac{0.715}{8.847} = 0.080$$
$$w_6 = \frac{u_6}{\sum_{i=1}^{n} u_i} = \frac{3.772}{8.847} = 0.420$$

So the weight vector

$$W = \{w_1, w_2, w_3, w_4, w_5, w_6\} = \{0.152, 0.266, 0.054, 0.028, 0.080, 0.420\}$$

Form the above calculations, we can find the most important factor that affects the necessity of the establishment of an aid to navigation in the traffic factor and the width of the channel.

3.4 Prove the necessity of establishing a lightvessel by questionnaires

Waterway and aids to navigation authorities should involve mariners and local pilots in the whole placement of AtoN in the waterway design process, including the program planning, the conclusions and subsequent recommendations, to make sure the acceptance. In this manner, individual and subjective opinions on operational margins can be avoided and a working environment of mutual trust can easily be created (IALA, 2011).

Navigating in restricted waters, a Pilot or Master of a large vessel can direct its movement with great precision and accuracy to avoid striking submerged dangers, colliding with other ship or grounding in shallow waters. So they have to use aids to navigation to ensure the navigational safety, this is why we invited 30 Pilots and Masters to do the following questionnaire. The necessity of setting the lightvessel is indicated by using questionnaire to collect the opinions of the crew and the pilot, and then do statistical analysis. The recipients of questionnaire here are 12 Pilots and 18 crew members. The 12 pilots are from Guangzhou Pilot Station, Shenzhen Eastern Pilot Station and Shenzhen Western Pilot Station, the 18 crew members are all officers from different classes of ships except the fishing vessel, High Speed Craft (HSC) included. No AtoN managers include in this questionnaire because we now care about the necessity instead of the maintenance difficulty of the lightvessel. (Wu, 2006)

Table 3.6 –Questionnaire on necessity and feasibility of setting Dan'gan Lightvessel

The necessity of setting Dan'gan Lightvessel	Very necessary	Necessary	Not so necessary	Unnecessary
Tick				
Reason or cause				
The feasibility of setting Dan'gan Lightvessel	Very feasible	Feasible	Not so feasible	Infeasible
Tick				
Reason or cause				

30 questionnaires were sent and 30 were returned in due time, the results areillustrated in the following figures.

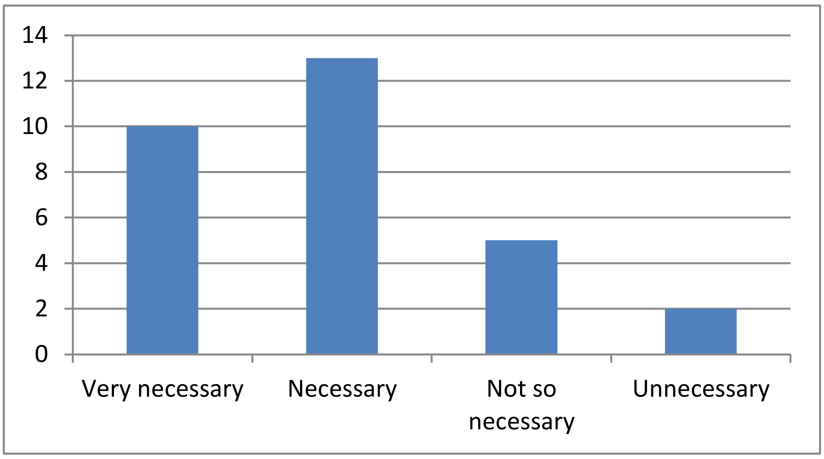

Figure 3.3 –The distribution on necessity of setting Dan'gan Lightvessel

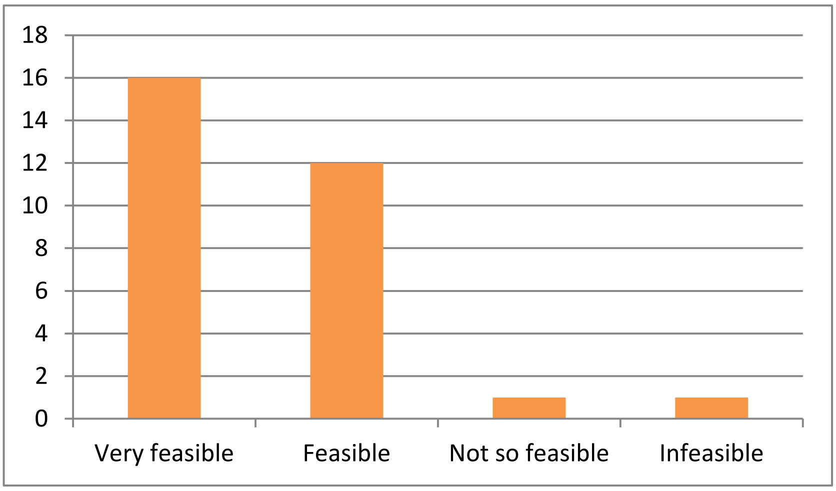

Figure 3.4 –The distribution on feasibility of setting Dan'gan Lightvessel

From the results of above investigation, it could be concluded that most surveyed people considered it essential to set up Dan'gan Lightvessel, however, those who thought it is unnecessary to insist that the safety could also be ensured if ships sailed along the direction of traffic flow and the crew were capable of ship maneuvering. As to the feasibility, the surveyed people agreed that it is entirely possible to set up a lightvessel in this area in terms of existing technical conditions. Therefore, in accordance to the above calculation and the results of the survey, setting up the Dan'gan Lightvessel is necessary and feasible.

3.5 Natural conditions

3.5.1 Meteorology

3.5.1.1 Air temperature

Based on data from Waglan Island and Wong Ma Kok meteorological stations north side to Dan'gan Waterway, temperature data over the years are as follows (Chen et al., 2011):

Perennial mean air temperature:	22.5 ℃;
Perennial maximum air temperature:	35.6 ℃;
Perennial minimum air temperature:	5.0 ℃;
Yearly average maximum air temperature:	26.0 ℃;
Yearly average minimum air temperature:	19.8 ℃.

3.5.1.2 Precipitation

There are moist air and abundant rainfall in Pearl River Estuary, According to the statistical data: (Jian et al., 2001)

Mean annual precipitation:	2382.7mm;
Maximum precipitation month, amount of rain:	June, 504mm;
Minimum precipitation month, amount of rain:	January, 25.1mm;
Daily maximum precipitation:	386.0mm;
Hourly maximum precipitation:	101.6mm;
Annual rainfall days:	107d;
The longest continuous rain days in a year:	10d.

3.5.1.3 Wind regime

3.5.1.3.1 Monsoon

The South China Sea is the world's most famous monsoon climate zone; the wind here has obvious seasonality.

The northeast monsoon period is from middle October to the next middle March, wind in this time is strong and stable, general level is 4-5; the southwest monsoon period is from middle May to middle September, Wind is weak and direction is not stable, wind power is 3-4. (Zeng et al., 2005)

3.5.1.3.2 Typhoon

Typhoons in the south China sea including two kinds, one is the south China sea generated, the other is generated in the western Pacific and then into the south China sea.

Typhoons which generated in South China Sea are generally weak, the center wind force is always about 9 to 12, wind range is small, and produce quantity is less, the annual average number of 4.9. Typhoons generated in South China Sea from June to November account for 88.9% of the whole year; the number among them in September is the most, accounting for 19.3%.

Typhoons which generated in Western Pacific and come into the South China Sea are strong, generally large range, 6 class wind radius of 250 to 350 n-miles. This kind of typhoon averaged 5.7 per year. Monthly average in September and October are the most, about 1 per month respectively. (Luo & Luo, 2009)

3.5.1.4 Fog condition

The Pearl River Estuary is one of the four foggy areas in South China Sea. The foggy season lasts from December to the nest May, March is the foggiest month. Fog day in a year reaches more than 24 natural days. Fog day duration is generally 2-3 natural days.

The fog condition may affect the extent which solar panels absorb sunlight to generate electricity.

3.5.1.5 Thunderstorm

The annual average thunderstorm is 34 days, which appear in spring and summer. The thunderstorms mostly appear from April to September. thunderstorms are less from October to next March.

3.5.2 Hydrology

The lightvessel will be set in Dan'gan Waterway, mainly affected by tides. Data of these tides are all from Dan'gantou tide station, which located in the eastern sea area of Lingdingyang mouth, south to Hong Kong Special Administrative Region (HKSAR).

3.5.2.1 The tides and water level

The tide in this area belongs to irregular semidiurnal tide. Dan'gantou Tide Station is an important tide station in the Pearl River Estuary. Due to the special geographic location，the station has not linked to the datum of Pearl River and used the reference datum. This has limited the popularity of the tidal data, suppose the elevation is 6.414 m.

The yearly average of tidal level is calculated by picking the hourly tidal level process of Dan'gantou Tide Station from 1990 to 2008. The average amplitude is 0.17 m and the average tidal level for many years is 2.03 m. (Wang, 2009)

3.5.2.2 Wave

Waters wave's frequency is greater than the surge in this area. The ordinary wave direction is SE, but there are 2 high-amplitude wave directions: NE-SE, SSE-WSE. The average wave height is 1 m while the maximum wave height can reach 4 to 5 meters. Rough stormy waves are mainly caused by the typhoon, they are generally more than 5 meters' high, up to 15 m or more, can cause big damage to banks and ships (The Committee, 1998). So the Lighthouse Authority should pay more attention to bad weather such as thunderstorm and typhoon.

3.5.3 Topography, landform, and sediment movement

The lightvessel plans to be deployed in open waters, where width can reach 6 n-miles, depth can be up to 25 meters, so there are little effects on topography for the project.

This project mainly consider positioning the lightvessel by anchoring, and the seabed of Dan’gan Waterway is mainly made of mud and silt, the depth of the water is not so deep, all of these can guarantee the reliability of anchoring and accuracy positioning the lightvessel.

The natural conditions show that set a light vessel in the second precautionary area of Dan’gan Waterway Routeing System is feasible.

Chapter 4

Design of the lightvessel

The process of designing a buoy (lightvessel included) to meet specific requirements involves but not limited to the following:

a) *Defining the operational performance characteristics;*

b) *Defining the equipment, power requirements and power source(s);*

c) *Defining the type and capabilities of the vessels that will be used to service the buoy;*

d) *Selecting the initial type proportions and mooring for the buoy;*

e) *Integrating of equipment and power supply;*

f) *Considering of the maintenance requirements;*

g) *Identifying deployment and recovery techniques;*

h) *Protecting equipment from damage;*

i) *Providing the ability to rectify faults without having to lift the buoy;*

j) *Determining the buoy response to the wave, wind, and current conditions at the site(s);*

k) *Optimizing design.* (IALA-AISM, 2006)

The type, height, power, light and other equipment of the lightvessel are to be considered in this research paper.

4.1 Current types of the lightvessels

After extensive investigation and data checking, the author collected some information of similar lightvessels along the coast of China. From the result of the research, there are mainly two different types of hull under water. One type is relatively small streamline form under waterline; the other is relatively full like a pontoon boat under waterline. From the perspective of the structure of the upper bracket, there are also two kinds. One is column shaped as a lighthouse; the other is using lever type to be connected with the profile of truss structure.

Now we choose two lightvessels to compare the difference and find which one is suitable in this program.

4.1.1 Zhongshajiao lightvessel

Figure 4.1- Zhongshajiao lightvessel

Source: http://www.ngcn.net/

Zhongshajiao lightvessel is located in Qingdao Jiaozhou bay, it is the streamline form, the total length of 25.35 meters, 8.14 meters wide (length-width ratio is about 3.1:1), 3.2 meters deep, 10 meters light- high, displacement of 137 tons, three layers LED lamp uses solar batteries to supply power.

4.1.2 Guishanbei lightvessel

Figure 4.2- Guishanbei lightvessel

Source: http://www.ngcscs.org/Index.html

Guishanbei lightvessle situated in the ring center waters of Dahao waterway traffic separation scheme of Pearl River Estuary, the main hull of the ship is tunnel bottom pontoon boat hull, the total length of 13.8 meters, 6 meters wide (length-width ratio of 2.3:1), 3.2 meters deep, the draft of 1.7 meters,and displacement of about 91 tons.

From the characters of the two types, because of the small block coefficient, the streamline shaped vessel can hold the direction of itself; Pontoon type vessel has better ability to resist wind because of the wider waterline. Considering the two types are relatively mature, this study will carry out two schemes respectively.

4.2 Details of the designed lightvessel

This vessel is a lightvessel used as Aids to Navigation, it is a steel, welding non-self-propelled vessel. The ship adopts streamline form, in order to improve the light ship wave resistance; bilge keels are installed on the bilge.

4.2.1 Main Parameter

Main parameter of scheme 1 refers to Table 4.1 and Figure 4.3 show the shape of the lightvessel.

Table 4.1- Main parameter of scheme 1

Length overall （L_{OA}）	23.8 m
Overall breadth （B_{MAX}）	8.0 m
Molded Depth (D)	3.2 m
Designed Draft （d）	1.7 m
Displacement（Δ）	134.6 t
Light height (from the deck surface)	10 .0 m
Room height	2.2 m
Handrail height	0.6 m
Frame spacing	0.5 m
Camber	0.15 m
Anchor weight	10 t

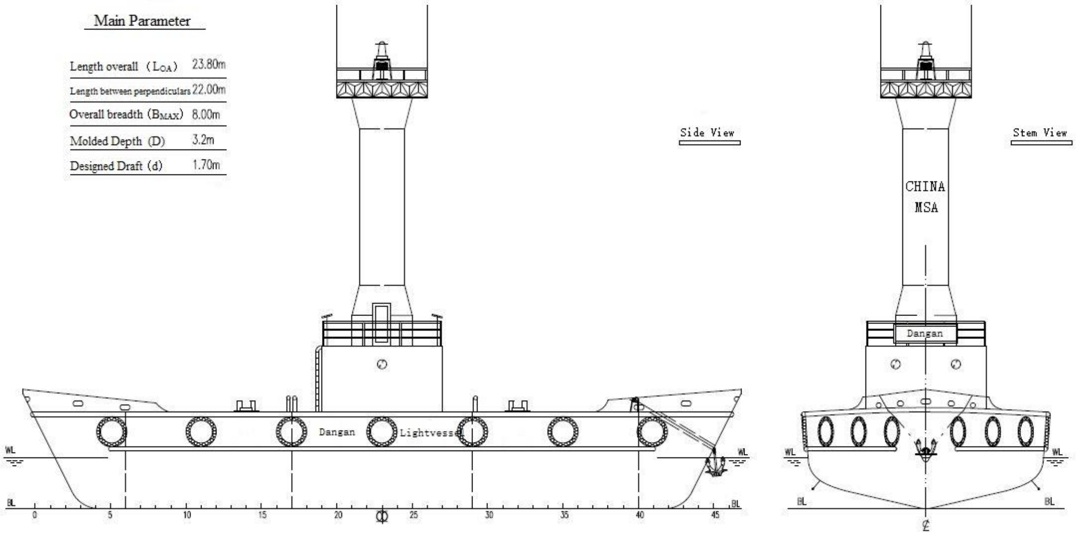

Figure 4.3 –Design drawing of scheme 1

Main parameter of scheme 2 refers to Table 4.2 and Figure 4.4.

Table 4.2- Main parameter of the scheme 2

Length overall （L_{OA}）	18.8 m
Overall breadth （B_{MAX}）	8.0 m
Molded Depth (D)	3.2 m
Designed Draft （d）	1.7 m
Displacement（Δ）	153.5 t
Light height (from the deck surface)	10.0 m
Room height	2.2 m
Handrail height	0.6 m
Frame spacing	0.5 m
Camber	0.15 m
Anchor weight	10 t

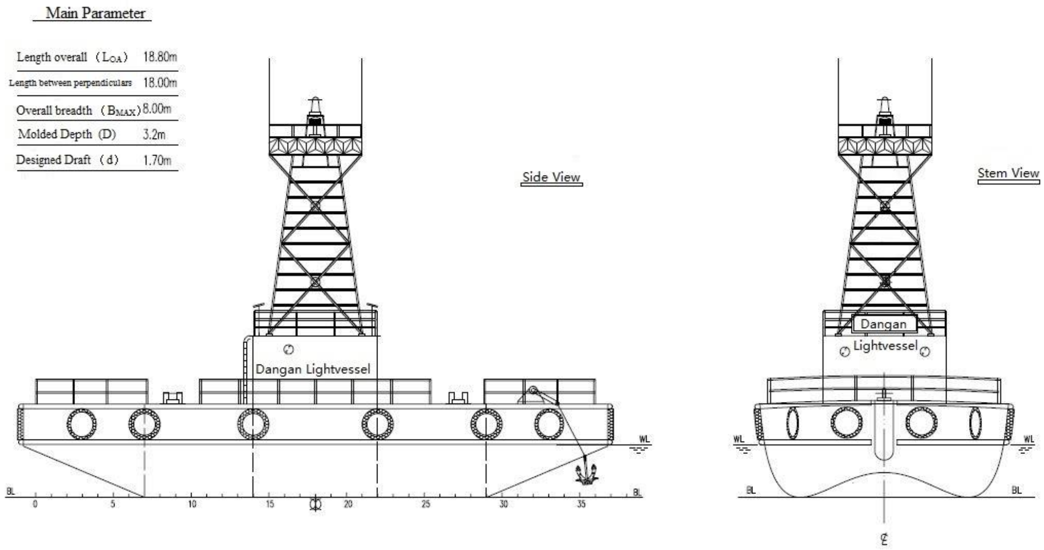

Figure 4.4 –Design drawing of scheme 2

4.2.2 Stability

Lightvessel as a navigational mark should have a certain ability to resist the wind and waves. With respect to the CHINA MSA "ships and offshore installations of legal inspection technology rules, domestic sailing ships statutory inspection technology rules" (2011) and the fourth modification notification of ship safety chapter 7 intact stability requirement of coastal area stability criterion, stability satisfy any 2 tanks flooded after balance, the final waterline is not above the freeboard deck. (Zheng, 2013)

4.2.3 Mooring system

The mooring system must maintain the floating aid in a sufficiently accurate position for it to perform its function as an AtoN. The mooring consists of a flexible cable connecting the floating AtoN to an anchoring device.

In most cases we will be considering a buoy connected by a length of mooring cable to a sinker on the seabed. However the concepts described can equally be applied to large floating aids such as lightvessels moored with anchors. With respect to the actual situation of this lightvessel, the mooring system should have strong ability to compromise the wind resistance trend, prevent the lightvessel shift or loss.

The shorter the link chain is, the more links per length it requires. And then it is heavier and more expensive, but it is easier to be handled by a winch. However the links may not be of sufficient size to accept a joining shackle and enlarged end links may be required on each length of chain. Long lengths of chain can then be cut to the required length for a particular mooring. It is easier to handle with a hook and permits one size of hook on the hoisting equipment to be used for several sizes of chain. (IALA, 2010) There is also less chance to knot. We choose the 4d chain as the mooring chain here.

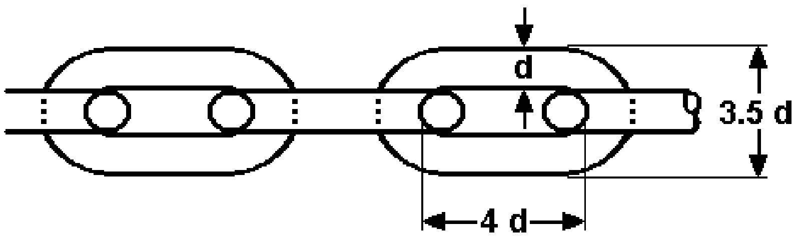

Figure 4.5 4d chain

Source: IALA Guideline 1066 – The Design of Floating Aid to Navigation Moorings

Anchoring and mooring equipment matching a weight for a 10 t stainless steel anchor, use the 4d anchor chain of which the diameter is φ70mm. In accordance to the depth of location, a total 3 chains is needed.

4.2.4 Painting and anti-corrosion

This steel of the lightvessel shall be used for surface pretreatment before use, and protection primer coating timely, catch up on in a timely manner if there were chipped primer after welding and machining. Shell plating (tail sealing board included) below the main deck surface need to spray zinc instead of marine primer, thickness of spraying zinc is 150 μm. Zinc spraying can effectively reduce the corrosion of plating; prolong the service life of the ship. Furthermore, Binding 20 zinc sacrificial anode plates on ship plate to prevent corrosion.

4.3 Compare the two types and choose the proper one

To satisfy the navigation efficiency of the lightvessel, this research paper put forward two construction schemes. The following table is the comparison of the major parameters.

Table 4.3 – Comparison of scheme 1 and scheme 2

Project	Scheme 1	Scheme 2	comparison
1. lightvessel			
Main Dimension (m)	23.8×8×3.2×1.7	18.8×8×3.2×1.7	
Block Coefficient	~0.45	~0.6	Scheme 2 is better
Displacement (t)	~134	~153.5	Scheme 2 has larger displacement and more expensive than Scheme 1
Stability of Ship	Meet requirements	Meet requirements	
Line type	Streamline	Pontoon type	Scheme 1 adapt to repeated tidal flow environment, have less aerodynamic resistance and better adaptability.
2. Performance of aids to navigation			
Shape of mark	Cylinder-shaped	Steel Frame	Target is more apparent of scheme 1, smaller wind area of scheme 2

From the perspective of hull form and Principal ship dimensions, the pontoon type linear solution of scheme 2 need more materials, and block coefficient is bigger than scheme 1, in order to achieve the corresponding draft, more ballast load is needed, these will result in increased construction cost directly where there is no difference in other aspects; but the pontoon line has larger displacement, lower center of gravity, a better ability to resist the wind and waves. In terms of performance, streamline form is more suitable for reciprocating flow of Dan’gan Waterway. (Eusterbarkey, 2006) Therefore, from the aspects of ship form, the streamlined body of scheme 1 is better. From the point of navigation performance, scheme 1 using the cylindrical beacon frame, the target is more apparent, so scheme 1 is a better choice.

4.4 Lightvessel navigation performance design

4.4.1 Navigation performance requirements

(a) Range of visibility greater than 4 miles during the day.

(b) Aid to navigation lights range greater than 8 miles at night.

(c) Configure virtual AIS AtoN, racon and radar reflector.

4.4.2 Height of the lightvessel

Visual Range is the maximum distance at which the contrast of the object against its background is reduced by the atmosphere to the contrast threshold of the observer. The visual range can be interpreted as the distance which a given light is seen by an observer with good eyesight. Light coming from an aid to navigation may not be visible in a certain distance because of two reasons: one is Light scattered or absorption and scattering in the atmosphere and make the observer cannot feel light; the other is light blocked by the earth's spherical surface so that cannot reach the observer's eyes.

As a result, Visual Range can be divided into Luminous Range and Geographical Range. Generally, the two numbers are not matching; Visual Range is limited to the smaller one. So when setting the lightvessel, how to choose height of light and light intensity, should be considered fully.

As per the China Sea area lights and large buoy system regulation, lightvessel topsides paint in red. The height of the lamp is calculated based on the geographical range of day requirements. It can be refered the geographical range to Table 4.4.

Table 4.4- IALA Geographical Range Table

Geographical Range in Nautical Miles											
Observer eye height / meters	**Elevation of Mark / meters**										
	0	**1**	**2**	**3**	**4**	**5**	**10**	**50**	**100**	**200**	**300**
1	2.0	4.1	4.9	5.5	6.1	6.6	8.5	16.4	22.3	30.8	37.2
2	2.9	4.9	5.7	6.4	6.9	7.4	9.3	17.2	23.2	31.6	38.1
5	4.5	6.6	7.4	8.1	8.6	9.1	11.0	18.9	26.9	33.3	39.7
10	6.4	8.5	9.3	9.9	10.5	11.0	12.8	20.8	26.7	35.1	41.6
20	9.1	11.1	12.0	12.0	13.1	13.6	15.5	23.4	29.4	37.8	44.2
30	11.1	13.2	14.0	14.6	15.2	15.7	17.5	25.5	31.4	39.8	46.3

Source: http://www.iala-aism.org/

We can also calculate what we want from the following formula:

$$R_g = 2.03 \times \left(\sqrt{h_o} + \sqrt{h_m}\right)$$

where:

R_g = geographical range (nautical miles)

h_o = elevation of observer's (meters)

h_m = elevation of the mark (meters)

The refraction in the atmosphere can be different all around the world; the typical range of factor is 2.03 to 2.12. Here we use 2.03 in the Pearl River Estuary area. Considering the ships navigating here, we set the h_o as 5 m, h_m as 10 m, so the calculated R_g is 10.8 nautical miles. This result can meet the requirement here.

4.4.3 Aids to Navigation Lights

Aids to Navigation light apparatus is an important aids to navigation equipment, it has a direct impact on the quality maintenance of aids to navigation, specific requirement which is the visual range of the night lights must meet the needs of the ship's reference at night, it is an important technical indicator to ensure the night function of aids to navigation to give full play.

There is a difference between visual range of aids to navigation light and the visual range of the lightvessel itself. The former depend on the light in the night, the latter based on the visual range of the lightvessel in the daytime.

4.4.3.1 Main technical requirements of the aids to navigation light

4.4.3.1.1 Visual range and rhythmic character of the aid to navigation light

As discussed above, in order to meet the requirement of navigation performance, the visual range of this lightvessel should be around 10 nautical miles.

In accordance tothe regulation of "Maritime lightvessels and large buoy system China" (GB 15359-1994), and considering other aids to navigation in this area, this lightvessel choose single-flashing white light with a period of 6 s (light 0.5 s; dark 5.5 s) as its rhythmic character. (CHINA MSA, 2012)

4.4.3.1.2 Luminous intensity of an aid to navigation light

Based on "Luminous intensity measurement and luminous range calculation of a navigation light" (JT/T 730-2008 replacement of JT/T 7007-1993), when an aid to navigation light is flashing so that it cannot be measured directly, the effective intensity can be calculated by using the following formula:

$$I_e = \frac{I_o \cdot t}{t + a}$$

where I_e is the effective luminous intensity with a unit of candela (cd); t is the duration of light, here is 0.5 (s); a is visual time constant, in revolving lamp, a =0.3, while in flasher lamp a =0.2. This lightvessel will be equipped with a LED lamp, so a =0.2 here.

The illumination of a light source reaching an observer's eye determines whether the given light is seen. The relationship of luminous intensity and light range is given by Allard's Law:

$$E = \frac{I_e \times T^d}{d^2}$$

where:

E =0.686 (lm/m^2): illuminance at the observer's eye

T =0.74: atmospheric transmissivity

d =10 (n mile) or 1852(m): distance between the light source and the observer

Note: Because T is measured per nautical mile, d in the numerator must also be in nautical miles. In the denominator, d is in meters.

So,

$$I_e = \frac{E \times d^2}{T^d}$$

I_e (cd): effect intensity of the light source is 1393 cd, then I_o is 1950 cd here.

4.4.3.2 Type selection of the aid to navigation light

At present, high efficiency LED lamp and halogen tungsten lamp are widely used in coastal and inland aids to navigation light source. From the point of usage, energy saving, reliability, LED lamp has less power consumption and higher reliability. So the MLED 300 lamp is chosen.

4.4.4 AIS station as an AtoN

Application of AIS terminal as an AtoN can make ships obtain the real-time navigation information and digital display on the screen, it has a very positive role in increasing the understanding of ships' position and other relevant information by navigating ships, improving the ship navigational safety, increasing the efficiency of the aids to navigation and improving the navigation efficiency of channel, it is an important means of using information technology to extend functionality traditional beacons. AIS terminal together with the remote system with AIS and VTS, CCTV, GPS system integration, not only provide timely beacon working state for AtoN managers, but also provide more direct beacon position and information services to ships.

So install an AIS AtoN on the lightvessel, sending indicating name, location precision, positioning device type, time, marks, virtual beacons by AIS AtoN message, it can warn the sailing ship. Through the linkage system of AIS and GPS dynamic monitoring system, combined with the beacon of the minimum safety distance requirements, set security distance for each controlled beacons (e.g., set to 30 m and 60 m, etc.), when ships close to the range, there will be an automatic alarm, and the information of ship track will be recorded. This can alert ships to avoid collision, even if a collision happened, the offending ship could be easily searched.

In order to ensure the work efficiency of the AIS terminal, which can be installed in the battery box, make sure it always has the power supply.

4.4.5 Choose the proper radar beacon (Racon)

Table 4.5 Technical Parameters for a General Purpose Maritime Radar Beacon (racon)

Item		Specifications
1 Antenna	Polarization	In the 9 GHz band, suitable for responding to radars using horizontal polarization. In the 3 GHz band, suitable for responding to radars using horizontal polarization and to radars using vertical polarization
2 Receiver	1 Frequency band 2 Blocking period 3 Primary radar pulse length	9 300 - 9 500 MHz and/ or 2 900 - 3 100 MHz. (9 300 – 9 320 from 01 January 2001) 100 μs after end of response. 0.05 μs.
3 Transmitter	Frequency	Transmission should occur either: • on the frequency of the interrogating signal with a frequency tolerance of ±3.5 MHz for interrogating pulses with a duration of less than 0.2 μs, or , with a frequency tolerance of ±1.5 MHz for pulses with a duration equal to or more than 0.2 μs,

		or • by a series of sweeps covering the entire frequency band of the receiver in which the signal was received. Where the transmission consists of a series of sweeps, the form of the sweep shall be sawtooth and should have a slew rate of between 60 s and 120 s per 200 MHz.
4 Respons e	1 Delay after receipt of interrogatio n 2 Form of identificatio n 3 Duration	Normally not more than 0.7 μs. Identification coding should normally be in the form of a Morse letter. The identification coding used should be as described in appropriate navigational publications. The identification coding should comprise the full length of the radar beacon response and, where a Morse letter is used, the response should be divided with a ratio of one dash equal to three dots and one dot equal to one space. The coding should normally commence with a dash. The duration of the response should be approximately 20% of the maximum range requirement of the particular radar beacon, or should not exceed five miles, whichever is the lower value. In certain cases, the duration of the response may be adjusted to suit the operational requirements for the particular radar beacon (see Note 1)

Source: IALA (2004). *IALA Recommendation R-101 on Marine Radar Beacons (racons) Edition 2.* Paris, France

The current domestic uses of mature radar beacon are the following types respectively: HY – II, and SeaBeacon 2. Compare the two kinds of racons, we can find all of them can meet the IALA standards. The author went onboard the ship “Haixun172” in May 2012, to do the range and position test of 20 racons around the Pearl River Estuary and analyzed the data in Table 4.6. (Chang, 2012)

Table 4.6 - Test outcome

Name of the AtoN	**Type**	**Measured distance /(n mile)**	**Signal intensity**
Lianhuashan Lightvessel	HY – II	6	strong
Shanbanzhou Lighthouse	HY – II	NO SIGNAL	--
Kaifeng K1# buoy	HY – II	7.78	weak
Tonggu No.17 buoy	HY – II	5.87	weak

Qingzhou Light Beacon	HY – II	6.92	strong
Guishanbei Lightvessel	HY – II	NO SIGNAL	--
Zhuzhou Lighthouse	SeaBeacon 2	10	strong
Sanyapai Light Beacon	SeaBeacon 2	7.22	strong
Beiyanjiao buoy	HY – II	4.5	medium
Xiaoputai Lighthouse	HY – II	2.54	weak
Gaolan No.1 buoy	HY – II	6.23	strong
Weijiadao Lighthouse	HY – II	NO SIGNAL	
Yangxi No.1 buoy	HY – II	3.5	weak

Source: Chang Peng (2012), *Analysis on Radar Beacons around Pearl River Estuary*

Compare the price of the two types, we can find SeaBeacon 2 is four times as HY-II, but SeaBeacon 2 is more stable and has better Signal intensity, so SeaBeacon 2 is choosed to be equipped in this lightvessel.

Table 4.7 - Morse code of the nearby Racons

Name of the AtoN	**Morse code**
Beiyanjiao buoy	Y (— . — —)
Wenweizhou Lighthouse	O (— — —)
Zhuzhou Lighthouse	N (— .)
Sanyapai Light Beacon	B (— ...)
Qingzhou Light Beacon	M (— —)
Xiaoputai Lighthouse	G (— — .)
Shanbanzhou Lighthouse	C (— . — .)
Guishanbei Lightvessel	Q (— — . —)
Mayoushi Lightvessel	K (— . —)
Tonggu No.17 buoy	B (— ...)
Kaifeng K1# buoy	Z (— — . .)
Dachanwan No.1 buoy	M (— —)

Source: http://183.62.26.194:81/default.aspx

In order to make it easy to identify, by referring to Figure 4.7, we use a different Morse code from the above, code X (—. .—).

4.4.6 Choose the proper Radar Reflector

A Radar Reflector is designed to return the incident radar pulses of electromagnetic energy back to the source thereby to enhance the response on the radar presentation. It is a passive device and can minimize the absorption and random scattering effects. There are two kinds of Radar Reflectors to compare with each other: SRR616 and LLJF500.

Table 4.8 - Main Technical Parameters of two kinds of Radar Reflectors

Type	SRR616	LLJF500
Angle of reflection	360°	360°
Reflective area	160m^2	30m^2
Material	Steel	Stainless steel
Weight capacity	100kg	80kg
Diameter	616mm	500mm
Height	661mm	450mm
Weight	35kg	10kg
Inner diameter of center pipe	φ24mm	φ20mm
Installation	4—M16⁄φ195mm	4—M16⁄φ195mm
Price	around 1500 RMB	around 1500 RMB

Two types of radar reflector in the table can both satisfy the requirement. LLJF Radar Reflector adopts stainless steel, its accept ability is strong, and has high reflectivity and corrosion resistance. Although the reflective area of SRR616 is much bigger, but it is not made up with stainless steel, once it got rusty, reflection effect will get worse. So, the LLJF500 is a better choice.

4.4.7 Remote unit

Aids remote monitoring system provides real-time monitoring to the Aids to Navigation, collects data to solve the traditional model of beacon inspection passive found problems. So as to enhance the stability of the lightvessel, a remote unit is needed. (Sinha, 2006)

The Navigation Guarantee Center of South China Sea (NGCS) had formed a group to make a research on Aids remote monitoring system of South China Sea. From the report of the group we know that up to the end of 2014, there are 2041 aids to navigation in South China Sea, but only 767 aids to navigation had equipped the remote unit. The percentage of Aids remote monitoring system is only 38% (Chang, 2015).But this system is really a good means for the modernization of the maintenance and management of aids to navigation in the future. So we must install a remote unit on the lightvessel.

4.4.8 Power Supplies

The lamp, AIS unit, Remote unit are all need the power supply of the lightvessel. It is therefore of most importance to choose the proper power supply in light of achieving their optimal working status.

4.4.8.1 Types of Power Supplies

Lots of different kinds of power systems and energy source have been used or contemplated to use on aids to navigation. The range is so wide that from clockwork to radio-active isotopes has been used. The usual types are listed in Table 4.9.

Table 4.9- Power sources for operating lighted aids to navigation

Electric Power Systems	**Non-Electric Energy Source**
Primary cells	Acetylene
Commercial power supply	Propane
Diesel and petro engine driven generators	Butane
Photovoltaic solar modules	
Wind generators	
Wave activated generators	

Source: IALA Guideline 1042 on Power Source and Energy Storage for Aids to Navigation

Nowadays there is a general trend away from gas, using mains electricity instead; the floating aids mainly use photovoltaic solar power where utility electricity is not available.

Consider the lightvessel is so big that a wind generator (or wind turbine) can be fixed on it, may be the wind can be a complementary power to the solar power. The most popular type of wind generator is horizontal axis machines with a two bladed turbine, something shaped like a propeller. But the maintenance requirements arising from the moving parts design of wind generators and susceptibility to storm damage has limited the use of wind generators. (IALA, 2004) So the only thing need to consider is the choice of silicon solar cell.

The two common technologies employed in the silicon based solar modules manufacture are listed in Table 4.10.

Table 4.10 – Silicon solar cell technology

Type (Technology)	Comments
Monocrystalline cells	● Are made from a thin slice cut from a single large crystal of silicon, usually produced as a circular section rod. ● Generally have the highest efficiency of the two technologies. ● If circular wafers of silicon are used the module fill factor is significantly less than with polycrystalline cells. It is now usual for the cells to be trimmed to approximate a square.
Polycrystalline cells	● Are made from a thin slice cut from a large cast billet of silicon comprising many crystals. ● Are slightly less efficient than the mono crystalline cell but they can be shaped to completely fill the module.

Source: IALA, Designing Solar Power Systems for Aids to Navigation

The prices of them are almost the same. Consider there will be enough space for the solar module. Both Mono crystalline and Polycrystalline are suitable here. Figure 4.6 shows the differences in appearance between Mono crystalline cells and Polycrystalline cells.

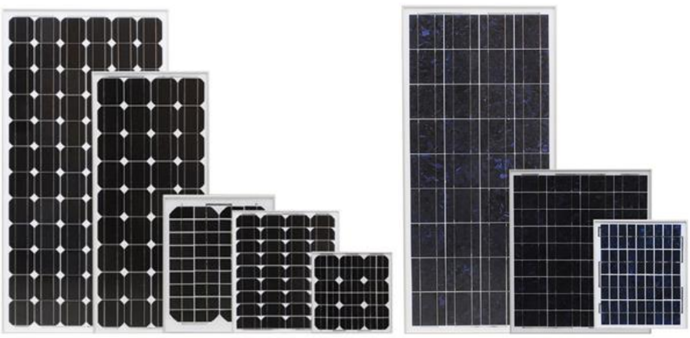

Figure 4.6 - Different solar modules (left: Mono crystalline; right: Polycrystalline)

4.4.8.2 Rechargeable Batteries

There are two main types of storage battery technologies applied to aids to navigation: nickel cadmium and lead acid. The nickel cadmium battery can operate for a greater number of deep discharge cycles and operate in lower temperatures. However, the lead acid type is generally preferred because of its lower cost and higher energy exchange efficiency (lead acid: nickel cadmium= 95%: 80%). This lightvessel will be set in Pearl River Estuary, the temperature there is above 10 centigrade degrees, so there will be no low temperature there.

In order to find the new suitable materials to apply to aids to navigation, a series of researches on lithium battery had been carried out by the author in 2013;. After a series of probation, I find the Ternary cathode materials lithium battery may have a good use on lighthouse (Chang, 2014). Because this kind of battery is much lighter than the lead acid battery, and do less harm to the environment. But it is not so good when it is used on the floating aids to navigation.

4.4.8.3 Battery capacity

Battery capacity is entered as Ah (Ampere hours) when the total battery bank is discharged over a 100-hour period. This will be a multiple of the capacity of the individual batteries. If an estimate is entered for the total battery capacity, then the program will calculate the number of days that the system will be able to work, without any solar gain, at the time of year when there is the minimum sunlight. It will also provide a graphical presentation of the solar system energy balance throughout the year (IALA, 2004). The calculation of battery capacity of the lightvessel should consider the main power consumption on board, including the lamp, aids remote monitoring unit, radar beacon, AIS, etc.

4.4.8.3.1 Power consumption of the lamp

To calculate the power consumption of the lamp, we should know how long an aid to navigation light works per day. Assuming that loads switch on at sunrise and switch off at sunset, the first step to determine daily loads is to calculate the hours of daylight or hours of darkness.

Set all calculations should be done in degrees,

Then:

$$H_{daylight} = \left(\frac{2}{15}\right) arc\ cos \left[\frac{-0.0151 - \sin(L) \times \sin(D)}{\cos(L) \times \cos(D)}\right]$$

Where:

$H_{daylight}$ = the number of hours between sunrise and sunset.

L = the latitude of site, positive values for northern latitude, negative values for southern latitudes.

D = the sun's declination, positive values for northern declinations, negative values for southern declinations.

Note:

The number -0.0151 is a number that has been derived to express the number hours of daylight that incorporates both the semi diameter and the refraction affects. The sun's declination ranges between 23.45 °S (-23.45 °) and 23.45 °N (+23.45 °). The day with the largest number of hours of darkness occurs on the date of the winter solstice. The declination on the date of the northern hemisphere's winter solstice is 23.45 ° S (-23.45 °). The declination on the date of the southern hemisphere's winter solstice is 23.45 °N (+23.45 °). (IALA, 2009)

And the position of this lightvessel is:

22°07′ 36.3”N; 114°13′ 32.2”E

Since the load operates at night, the greatest daily load occurs at the time of the winter solstice when the sun's declination is: D= -23.45 °

$$H_{daylight} = \left(\frac{2}{15}\right) arc\ cos\left[\frac{-0.0151 - \sin(22) \times \sin(-23.45)}{\cos(22) \times \cos(-23.45)}\right] = 10.8\ hours/day$$

So

$$H_{darkness} = 24 - H_{daylight} = 24 - 10.8 = 13.2\ hours/day$$

So we take 14 hours as the working time of the lamp. Therefore, the maximum daily consumption is:

$$S = \frac{L}{L + D} \times I \times H_{darkness} + i \times 24$$

Where:

S: Daily consumption of the lamp, (Ah).

L: Light time in a period of the light rhythmic character.

D: Dark time in a period of the light rhythmic character.

I: Rated current of the lamp, take it as 3 A.

$H_{darkness}$: Working time of the lamp, use the result of above calculation, 14 h.

i: Dark current which is always there, take it as 5 mA.

So:

$$S = 3.62\ Ah$$

4.4.8.3.2 Power consumption of other devices

The AIS terminal, Racon and Remote unit are all continuous firing patterns. Transmitted power of AIS terminal is less than 3 W, operating current of it is less than 250 mA, so the daily consumption of it is around 3 Ah; the operating current of the Racon is about 300 mA, so the daily consumption of it is approximately 3.6 Ah; the average working current of the Remote unit is 60 mA, so the daily consumption of it is approximately 1.5 Ah.

4.4.8.3.3 Number of the batteries needed

Power consumption of these devices per day is about 11.72Ah, in accordance to the weather conditions and waterway maintenance requirements of the South China Sea off shore, the minimum capacity of power supply should meet the lightvessel 20days normal light under continuous rainy or cloudy conditions, so the battery capacity will take about 234.4Ah.

In the selection of solar and battery-powered facilities in lighthouses or lightvessels' power supporting systems, battery capacity of selected is 500AH. Based on experience, the use of single 2V 500AH maintenance-free lead-acid batteries, a set of 6 series, can meet supply voltage of 12V DC.

4.4.8.3.4 Configuration of the supporting solar panel assembly

Consider minimum solar requirements which lights, racon and other equipment needed:

$$P = \frac{S}{K_1 \times P_1} \times K$$

where：

S = 21.72Ah；

K_1 : The efficiency of the batteries, take it as 0.80；

P_1 : Electricity which 1W Solar panels generate per day, take it as 0.35A/W;

K : The solar array correction factor, take it as 2.

So the calculated P is 155W. So as to match the battery, the peak power of monocrystalline silicon solar module panels is approximately 160W.

To be concluded this chapter mainly concerning about the design of the Dan’gan Lightvessel. We consider not only the conventional visual aids to navigation, but also the digital aids such as AIS terminal and Remote unit. They can be treated as an integration of Aids to Navigation in maritime operational and safety services.

Chapter 5

Evaluate the environmental protection affect and energy conservation effects of the lightvessel's construction, use and maintenance

5.1 Environment Protection

The vulnerability of the environment of Dan'gan Waterway to pollution damage, and the reliance of the fishermen upon that environment make environment protection in this area very important. The main pollution sources and pollutants are as follows.

5.1.1 Water pollution source

Water pollution sources are mainly the sewage and wastewater due to building process of lightvessel, waste liquid such as oil during the construction, while the main water pollution effects during lightvessel's layout and maintenance period are as follows: oil sewage of maintenance vessel, wastewater of maintenance people.

5.1.2 Air pollution

Air pollution mainly comes from waste and dust of welding, cutting, transportation during construction of the lightvessel, and the exhaust of ships which set and maintenance the lightvessel etc.

5.1.3 Noise pollution

Noise pollution mainly comes from machinery noise when lightvessel is under construction, etc.

5.1.4 Solid waste pollution

Solid waste pollution is mainly construction personnel life waste and production waste, etc. Life waste is mainly food scraps, health cleaning items, waste packaging, bottles and cans. Production waste is mainly leftover material, waste dregs of lightvessel building process, etc.

5.2 Environmental protection measures

In strict accordance with national standards to deal with waste water, solid waste or collected pollutants should be centralized treated. Life sewage, life rubbish must be centralized collected, centralized treated. Bilge oily water of aids to navigation maintenance ships should be treated by its own oil-water separator, discharge after meeting "the ship pollutants emission standards", or after collected at the dock designated place then do centralized treatment. Life waste and production waste on ships are strictly prohibited to drop into the sea; they should be disposed after collection to the shore.

5.3 Environmental impact assessment

This lightvessel uses the materials mainly for steel, aluminum alloy and its supporting the modulator of power supply, etc., these materials and equipment has been widely used in the coastal aids to navigation construction in China, and its application shows that the material nearly has no effect on environment.

The construction of lightvessel and equipment installation and debugging of the main production basically in the shipyard or other factories, the quantity is not big, and construction period is not long, the waste water produced during the construction and construction process is very little, due to the construction of the project within the shipyard, the affected area is small, and through the environmental protection measures, the waste handling can be effectively ensured, basically no influence on the environment.

After the completion of light ship's building, it will be set by ship towing to reserve water and do later maintenance work, the ship through the separation of slop, processing, after reaching the standards emissions or slop tank, by collecting, docked centralized collection processing, there will be no emissions in water.

The build-up of marine growth is not particularly detrimental on buoys and lightvessels, so in view of concentration of these types of aids to navigation in port approaches and waterways, less toxic paint systems will be preferred to minimize environmental pollution.

In conclusion, this project nearly does no harm to the environment.

5.4 Energy conservation measures

This lightvessel uses new LED light of low power consumption, it can greatly reduce the power consumption; it uses configuration of solar panel and maintenance-free lead-acid batteries, makes full use of natural energy, can save artificial energy transformation; on the premise of meet the requirements of performance and cost, equipment on the lightvessel will choose energy saving products.

Through the above a series of measures, in the process of daily operation, energy consumption can be effectively reduced, energy utilization level can be improved.

Chapter 6

Risk management and benefit assessment of the lightvessel

6.1 Establishment and operation of aids to navigation

SOLAS Chapter V, and Regulations 12 and 13 define the obligations on Contracting Governments to provide VTS and aids to navigation and related information in particular, the regulation states:

1. *Each Contracting Government undertakes to provide, as it deems practical and necessary either individually or in co-operation with other Contracting Governments, such aids to navigation as the volume of traffic justifies and the degree of risk requires.*
2. *In order to obtain the greatest possible uniformity in aids to navigation, Contracting Governments undertake to take into account the international recommendations and guidelines when establishing such aids.*
3. *Contracting Governments undertake to arrange for information relating to aids to navigation to be made available to all concerned. Changes in the transmissions of position-fixing systems which could adversely affect the performance of receivers fitted in ships shall be avoided as far as possible and only be effected after timely and adequate notice has been promulgated.*

6.2 The equipment availability

So in order to satisfy the obligations of Regulation 13, the Contracting Government has to make assessments on level of service of the aids to navigation. Level of service statements for quality is the equipment availability (IALA, 2013).

The equipment availability of the lightvessel is governed by the equipment operational reliability measured in terms of meantime-between-failure (MTBF) and the time to complete repairs in the event of a failure, measured in downtime or meantime-to-repair (MTTR). Where routine maintenance cannot be carried out during non-operational periods, an additional factor for planned downtime must be included. Equipment with very high reliability may achieve required availability standards, that is to say, with a long MTTR. (IALA-AISM, 2006)

6.3 Calculation of Availability

Here availability is the probability that the lightvessel is performing its specified function at any time. The availability of an AtoN may be calculated by using one of the following equations (usually expressed as a percentage):

$$Availability = \frac{(MTBF)}{(MTBF + MTTR)}$$

Or

$$Availability = \frac{Up\ Time}{Total\ Time}$$

Or

$$Availability = \frac{(Total\ Time - Down\ Time)}{Total\ Time}$$

6.4 Over or under achievement issues

The actual availability achieved by the lightvessel is a reflection of the quality of the establishment process, the skills of personnel and the maintenance regime involved. There is a cost penalty associated with prescribing a higher level of availability for the lightvessel, and there is also a cost penalty associated with the maintenance of unreliable systems. The interrelationship is complex, but the objective is to find the minimum cost solution as illustrated in Figure 6.1.

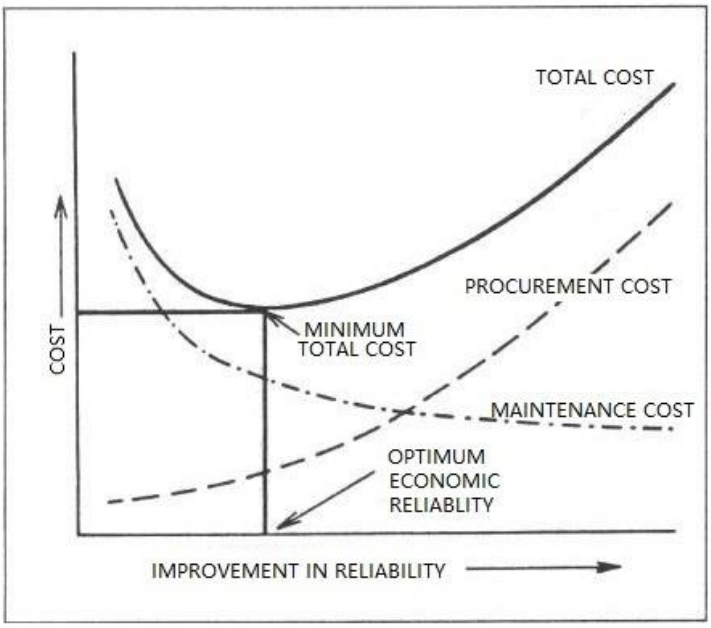

Figure 6.1 – The cost of reliability

Source: Shuo Ma. Unpublished handouts for MSEM 2016 students, updated by the author

So in order to prove the availability of the designed lightvessel, a risk management and cost- benefit assessment on the maintenance of it should be carried out in a certain period of time after establish of the lightvessel.

Chapter 7

Conclusions and suggestions

The heavy traffic flows make Dan'gan Waterway hazardous to shipping, particularly for vessels under the command of those unfamiliar with the conditions in the region. The complex traffic factors make the Dan'gan Waterway an area of great concern in the context of maritime safety.

A lightvessel with AIS beacon and Remote Unit is a current generation innovation, one that can contribute to safety and efficiency to transit the region. After the establishment of the lightvessel, the striking hull, bright lights and various kinds of aids to navigation on it, will provide reliable guarantee for ship safe navigation, increase aids to navigation efficiency, provide a better navigation security for the implementation of the Dan'gan Waterway ship routeing system. Furthermore, play higher ships routing system efficiency, improve navigation benefit, play an important role in the development of the shipping economy.

In this research paper, the AIS management system is used to observe the ships flow, but there are lots of small fishing vessels which don't carry any AIS terminal on them yet. Another shortcoming is the representative sample of the investigation is relatively small (only 30 people), so the consequence is not so strong in order to prove the necessity of the lightvessel. The third one is this research paper doesn't consider simulation when design the lightvessel. Simulation can be used as a tool in the design and planning of fairways, it also can be used a tool for waterway design and AtoN planning, for discussions on the use of simulation in fairway design and placement of

AtoN.

So in conclusion, when there is a possibility of establishing an aid to navigation system, the Lighthouse Authority should carry out surveys in the extent, quantity and quality for navigation guarantee measures, taking the nature and character of the area into account, working on traffic analysis, simulation and risk assessment at least.

REFERENCES

Chang, P. (2012). Analysis on Radar Bacons around Pearl River Estuary. *Maritime Observation, 12 (2012)* , 87-90.

Chang, P. (2014). Application Of The Ternary Material Lithium Battery As a Energy Storage on Aids to Navigation. *Technology of Aids to Navigation and Hydrography, 9 (2014)* , 11-13.

Chang, P. (2015). Current Situation of the Aids Remote Monitor and Control in South China Sea and Associated Contemplate on Its Future Development. *China Maritime Safety, 3 (2015)* , 42-45.

Chen, T., Tang, C., Nie, Y., & Yu, K. (2011). Study on the Relationship between Climate Warming and the Maximum High Sea Level at the Pearl River Estuary during 1910-2009 AD. *GUANGDONG METEOROLOGY, 4 (2011),* 1-3.

CHINA MSA. (2012). *Compilation of Law and Standard in Aids to Navigation and Surveying & Mapping.* Beijing.

E.Bal Besikci, e. a. (2016). An application of fuzzy-AHP to ship operational energy efficiency measures. *Ocean Engineering, 121 (2016),* 392-402.

Eusterbarkey, H. (2006). A STRATEGIC PLANNING AND DESIGN APPROACH FOR A COASTAL-WIDE NETWORK OF AIDS-TO-NAVIGATION. *XVIth IALA Conference* (pp. 34-42). Shanghai: IALA-AISM.

GD MSA. (2015). *Navigation Guidance of Dan’gan Waterway.* Guangzhou: Guangdong Maritime Safety Administration.

Guo, W., & Fan, Z. (2014, 2). Suggestions on Dan’gan Waters Ship Routeing System revision . *Navigation technology*, *2 (2014)* , 26-27.

Li, H. (2015). Research on Optimization of the Amending Schemes to Dan'gan Traffic Separation Scheme. Dalian, Liaoning, China.

Huang, Z. (2012). Study on the Quantitative Assessment of Rational Buoys Layout. *Journal of Wuhan University of Technology*, *10 (2012),* 1036-1039.

IALA. (2004). IALA Guideline 1042 on Power Source and Energy Storage for Aids to Navigation. Paris: IALA-AISM.

IALA. (2004). *IALA Guideline No.1039 on Designing Solar Power.* Paris: IALA-AISM.

IALA. (2009). *IALA Guideline No.1067-1 on Total Electrical Loads of Aids to Navigation.* Paris: IALA-AISM.

IALA. (2010). *IALA Guideline No.1066 on The Design of Floating Aid to Navigation Moorings.* Paris: IALA-AISM.

IALA. (2011). *The Use of Simulation as a Tool for Waterway Design and AtoN Planning.* Paris: IALA AISM.

IALA. (2013). *IALA Guideline 1004 on levels of service.* Paris: IALA AISM.

IALA-AISM. (2006). IALA Aids to Navigation Manual. Paris: China Communications Press.

IMO. (2003). *Ships' Routeing and Reporting Systems.* Dalian: Dalian Maritime University Press.

Jian, Y., Zhou, W., & Chen, C. (2001). The Characteristics of the Precipitation in Hongkong over the Last 150 Years. *ACTA SCIENTIARUM NATURALIUM UNIVERSITATIS SUNYATSENI, 2 (2001)* , 116-119.

Luo, Z., & Luo, Y. (2009). Analysis on Pearl River channels Impacted by Typhoon . *Proceedings of the 14th China Ocean Engineering Academic Seminar* (pp. 905-910). Hohhot: Chinese Society of Oceanography.

Sinha, D.K. (2006). Intergration of Aids to Navigation- The Emerging Scenario. *XVIth IALA Conference* (pp. 5-13). Shanghai: IALA-AISM.

Stopford, M. (2009). Sea Transport and The Global Economy. In M. Stopford, *Maritime Economics (3rd Edition)* (pp. 3-7). London & New York: Routledge.

The Committee. (1998). *Records of China Bays 14th Fascicule (Important estuary).* Beijing: China Ocean Press.

The National Development and Reform Commission. (2008). *The Outline of the Plan for the Reform and Development of the Pearl River Delta.* Beijing: The National Development and Reform Commission.

Wang, Y. (1997). *Aids to Navigation.* Dalian: Dalian Maritime University Press.

Wang, Y. (2009). Probe into Conversion between Reference Datum in Dan'gantou Tide Station and Pearl River Datum. *Pearl River, 6 (2009),* 31-33.

Wu, Z. (2006). *Identifying the Human Factors in Ship Collisions Based on the Investingation by Questionnairs.* Dalian: Dalian Maritime University Press.

Sheng, X. (2014). Research on Revising the Ship Routeing System of the Pearl River Estuary. *Pearl River Water Transport , 11 (2014),* 88-93.

Yang, L., & Liang, B. (2004). Demand Analyses of Aids to Navigation to Large Ships. *The China Institute of Navigation Beacon Professional Committee of Coastal Aids to Navigation Group Semina* (pp. 29-31). Dandong: CHINA INSTITUTE OF NAVIGATION.

Zeng, G., Hu, J., Hong, H., & Chen, Z. (2005). Analysis of Hydrologic Section off Zhujiang River Estuary in Northern South China Sea during Various Southwest Monsoon Phases. *Journal of Tropical Oceanography, 5 (2005),* 10-17.

Zheng, Y. (2013). *Bsaic Theory of Ship.* Dalian: Dalian Maritime University Press.

BIBLIOGRAPHY

Charles, L. (2011). *Cite Right: A Quick Guide to Citation Styles- MLA, APA, Chicago, the Science, Professions, and More (2nd Edition).* Chicago: The University of Chicago Press.

Chen, Y. (2012). *A Practical English-Chinese Maritime Dictionary.* Beijing: The Commercial Press.

Wu, P. (2011). *Approach Guide for Design Channels.* Beijing: China Communication Press.