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The selecting and risk analysis of temporary anchor positions in the port area of Qinhuangdao

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THE SELECTING AND RISK ANALYSIS OF TEMPORARY ANCHOR POSITIONS IN THE PORT AREA OF QINHUANGDAO

By

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The People's Republic of China

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Fulfillment of the requirements for the award of the degree of

MASTER OF SCIENCE

(MARITIME SAFETY AND ENVIRONMENTAL MANAGEMENT)

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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: **The Selecting and Risk Analysis of the Temporary Anchor Positions in the Port area of Qinhuangdao**

Degree: **MSc**

The research paper is about a research on the temporary anchor positions in Qinhuangdao port. The selecting process and risk analysis are the main content.

First, necessity of temporary anchor positions and navigation environment are introduced. The temporary anchor positions are used to improve the transport efficiency of the port.

Then through the analysis and calculation of the historical data, the key point to improve the transport efficiency for coal carriers is found out. Next, the plans of temporary anchor positions are analyzed. After comparison in many respects, the optimal plan is found out.

Finally, in order to verify the safety of the TAP, Formal Safety Assessment is introduced to analyze the risk. The result meets the requirements of the risk acceptance criteria. And the conclusion to the research of temporary anchor positions would be presented at last.

Keywords: Temporary Anchor Positions, Risk Analysis, Selecting, Statistics, Assessment,

TABLE OF CONTENTS

DECLARATION ii
ACKNOWLEDGEMENTS.. iii
ABSTRACT.. iv
TABLE OF CONTENTS.. v
LIST OF TABLES vii
LIST OF FIGURES viii
LIST OF ABBREVIATIONS x
Chapter 1 Introduction 1
1.1 Background of research 1
1.2 Necessity of the research 3
1.3 Objects of the research 4
Chapter 2 Basic data of the navigation environment 5
2.1 Port condition 5
2.2 Traffic situation 8
Chapter 3 Transport efficiency for coal carriers 10
3.1 Introduction to port capacity and efficiency 10
3.2 Time structure for vessels in port 12
3.3 Data analysis of the coal carriers 14
3.4 Efficiency analysis of the coal carriers 21
3.5 Measures for improvements of the transport efficiency 25
Chapter 4 Selecting and analysis of temporary anchor positions 27
4.1 Introduction to temporary anchor positions 27
4.2 The selecting of temporary anchor positions 30
4.3 Limitation of using temporary anchor positions 37
4.4 Efficiency analysis of temporary anchor positions 41
4.5 Route and navigation method 45
Chapter 5 Risk analysis for the temporary anchor positions in the port area 49
5.1 Introduction to the formal safety assessment 49
5.2 Preparation for the study 51
5.3 Hazard identification 51

5.4 Risk assessment 60
5.5 Recommendations 65

Chapter 6 Conclusion.. 67

References.. 69

LIST OF TABLES

Table 1-1 Throughput of Qinhuangdao port 2004-2013

Table 3-1 Statistics of coal carriers in 2013

Table 3-2 Average stay time in anchorage

Table 3-3 Average lay-time caused by natural factors and other factors

Table 3-4 Handling operation time

Table 3-5 Time distribution in port

Table 3-6 Time distribution of berthing time

Table 3-7 Average berthing time and stay time in anchorage

Table 3-8 Measures and effect for improvements of the transport efficiency

Table 4-1 Ship type

Table 4-2 Required depth of the TAP

Table 4-3 Comparison of locations

Table 4-4 Depth of the layout plan

Table 4-5 Comparison of layout plan

Table 4-6 Limitation on draft

Table 4-7 Radius of the anchoring circle

Table 4-8 Saved time and efficiency brought by TAP

Table 5-1 Accident data 2008-2013

Table 5-2 Data for accident frequency 2008-2013

Table 5-3 HAZID checklist

Table 5-4 Frequency index for risk analysis of TAP

Table 5-5 Severity index for risk analysis of TAP

Table 5-6 Risk index for risk analysis of TAP

Table 5-7 Risk acceptance criteria

LIST OF FIGURES

Figure 1-1 Illustration of the use of fairway

Figure 2-1 Overall layout of Qinhuangdao port

Figure 2-2 Drifting area for incoming vessels

Figure 2-3 Layout of the berths for coal transportation

Figure 2-4 Illustration of the relevant anchorages and fairways

Figure 2-5 Track line of the traffic flow from AIS database in August 2013

Figure 3-1 Distribution of deadweight tonnage in 2013

Figure 3-2 Extended area of east anchorage

Figure 3-3 Distribution of Stay time in anchorage in 2013

Figure 3-4 Time distribution of berthing time

Figure 3-5 Comparison between berthing time and stay time in anchorage

Figure 4-1 Area of single anchor position

Figure 4-2 Locations of TAP

Figure 4-3 Layout plan of TAP

Figure 4-4 Track line of the traffic flow from AIS database in August 2013

Figure 4-5 Affected area by current

Figure 4-6 Illustration of the chain length

Figure 4-7 Reference point on fairway 150

Figure 4-8 Navigable waters and route to enter TAP

Figure 4-9 Relation between route and traffic flow

Figure 4-10 Selected route for vessels using TAP

Figure 5-1 Five steps of FSA

Figure 5-2 Accident distribution

Figure 5-3 Causes of accidents

Figure 5-4 Risk contribution tree
Figure 5-5 Collision event tree
Figure 6-1 Layout plan of TAP

LIST OF ABBREVIATIONS

TAP	Temporary anchor position
MSA	Maritime Safety Administration
VTS	Vessel Traffic Service
HSE	Health Safety Environment System
HAZID	Hazard Identification

Chapter 1 Introduction

1.1 Background of research

Qinhuangdao Port, located in the central part of Bohai Bay, is the world's largest coal export port. With half of the coal export in China loaded here, Qinhuangdao port is one of the most important ports in China. Except financial crisis in year 2009, the port throughput has kept a steady growth increase since 2004 and stabilized at 270 million tons in the past two years.

Table 1-1 Throughput of Qinhuangdao port 2004-2013

Year	Total throughput (10,000 tons)	Coal throughput (10,000 tons)
2004	15,034.6	13,159.8
2005	16,900.3	14,513.9
2006	20,186.7	17,691.6
2007	24,569.0	21,419.2
2008	24,954.7	21,810.2
2009	23,956.3	20,633.0
2010	25,706.2	22,393.9
2011	28,769.8	25,400.4
2012	27,160.4	23,652.0

2013	27,301.9	23,689.7

Source: Qinhuangdao port authority, (2013).Historical data of Qinhuangdao port.

At present, coal is still in great demand in China, and lots of vessels sail to Qinhuangdao port for coal transportation. Because all the fairways are one-way, when the heavy loaded vessels leave the port, they use the fairway for a long time, and the incoming vessels have to wait in the anchorage. The berths are vacant in this period which reduces the transport efficiency.

In order to ensure the coal supply, Qinhuangdao VTS changes the original traffic organization. When the heavy loaded vessels use the fairway, the incoming vessels are allowed to wait in positions alongside the fairway which are close to the port, these vessels are in drifting condition with a low speed and not anchoring. Once the heavy loaded vessels pass their positions, they will get orders to enter the fairway. This method saves the navigation time of the incoming vessels on the fairway. It is shown in Figure 1-1.

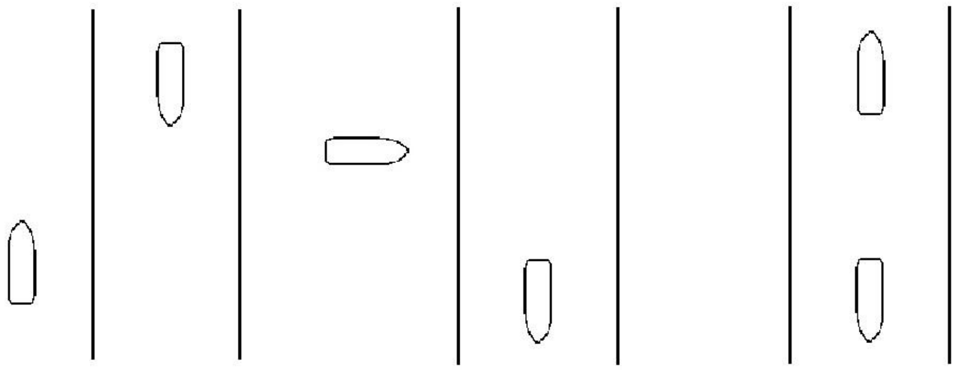


Figure 1-1 Illustration of the use of fairway.

Source: Compiled by author. (2014)

1.2 Necessity of the research

1.2.1 Demand of reducing potential risks

The method for incoming vessels waiting alongside the fairway improves the transport efficiency. But the waiting area has no definite function as other navigable waters, it is not treated as anchorage or fairway. If the time for vessels to enter the port is not confirmed, normally vessels are not allowed to heave up anchors, so the waiting period for the drifting vessels cannot be defined by current regulations. Once there is an accident, VTS will be held to be responsible for operation.(Song, 2011)

Meanwhile vessels with a quite low speed in the drifting condition reduce the maneuverability of the vessels and could be easily affected by wind and waves. The wait waters are traffic intensive area, the drifting vessels lack the ability for collision avoidance, and the collision risk is very high.

The temporary anchor positions (TAP) transform the status of the vessels from drifting to anchoring, and the function of the waiting area becomes legal. Also the responsibility for collision avoidance changes, vessels navigating near the TAP should keep clear of the anchoring vessels in TAP. Compared with the drifting condition, it is much safer.

1.2.2 Demand of the port throughput growth

It has been estimated that with the fast development of economy, the demand of coal will increase. Qinhuangdao port needs to supply more coal to the market, the throughput will continue to grow. Because of the limited shoreline resources, the size of the port cannot be expanded, and the transport efficiency becomes the only way to increase the throughput.(Project and Design Institute of Ministry of Transportation of China, 2009) TAP reduces the vacant time for the berths and speeds up the turnover of the ships and therefore effectively support the port throughput growth.

1.3 Objects of the research

In Qinhuangdao port, the coal handing operations are mainly on the berths of Second branch, sixth branch, seventh branch and ninth branch of the port authority. The targets of the research on selecting of TAP are vessels using the above berths, and the targets of the research on risk analysis of TAP are vessels in port waters.

Chapter 2 Basic data of the navigation environment

2.1 Port condition

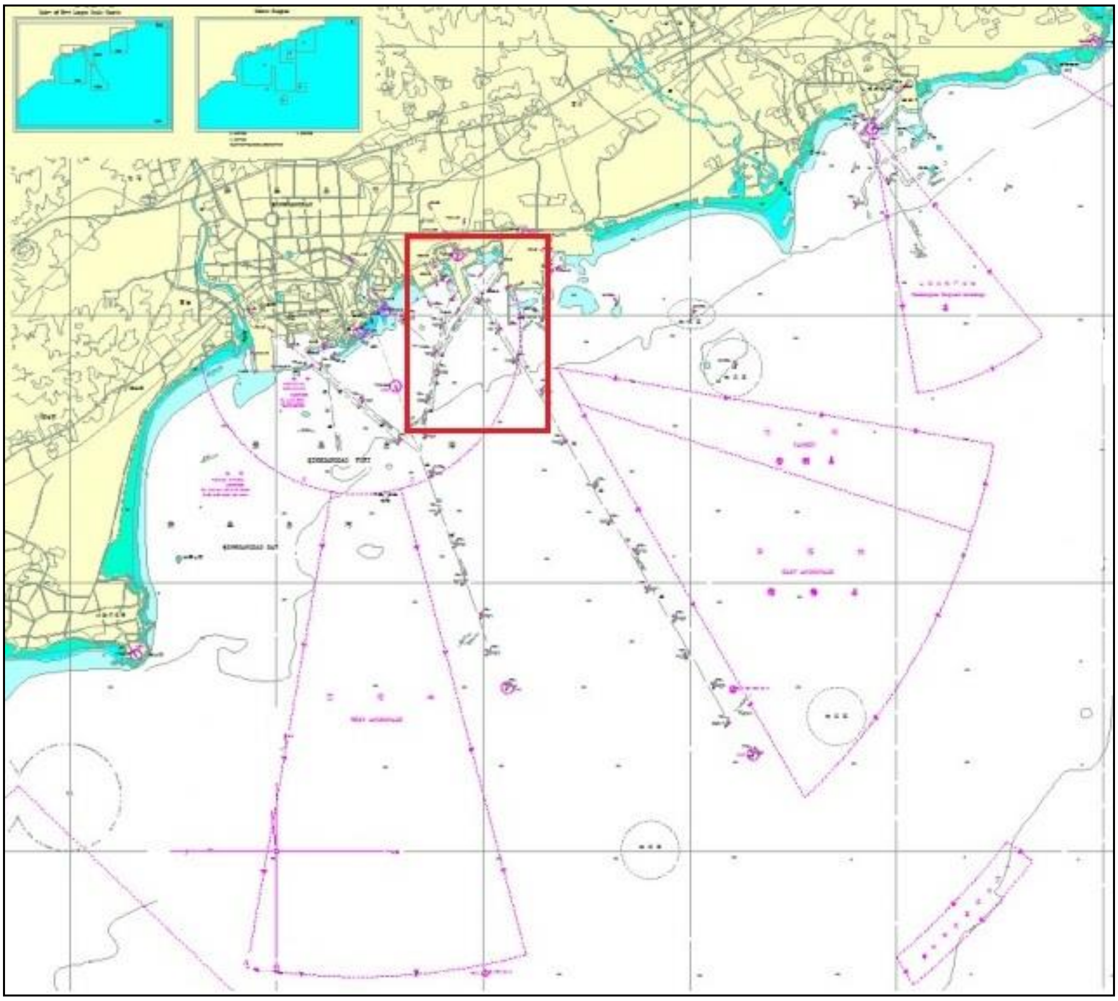


Figure 2-1 Overall layout of Qinhuangdao port

Source: Chart 21001, (2011), China MSA.

Qinhuangdao port approaching areas can be divided into three port areas, nine fairways and five anchorages. The temporary anchor positions (TAP) related area is the eastern port area which has been marked in red rectangle. The area for incoming vessels to wait alongside of the fairway in drifting condition is also in this area, marked as the circle in Figure 2-2.

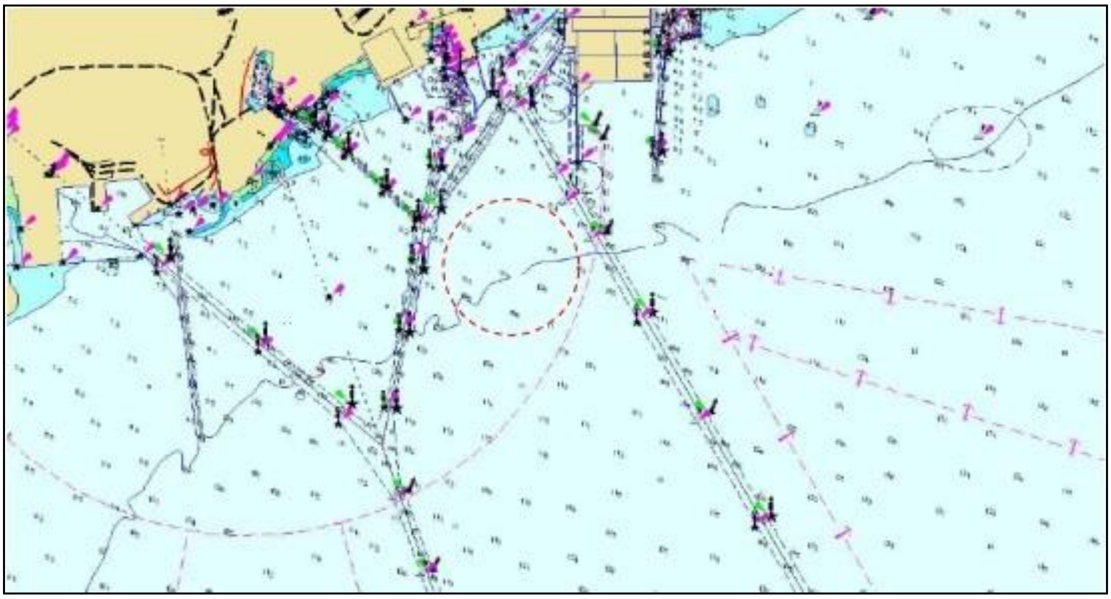


Figure 2-2 Drifting area for incoming vessels

Source: Chart 21115, (2014), China MSA.

2.1.1 Layout of the berths for coal

There are 20 special berths for coal handling operation in Qinhuangdao port, and their layout has been shown in Figure 2-1. The capacities of these berths are 50,000 tons, 70,000tons, 100,000tons and 150,000 tons.

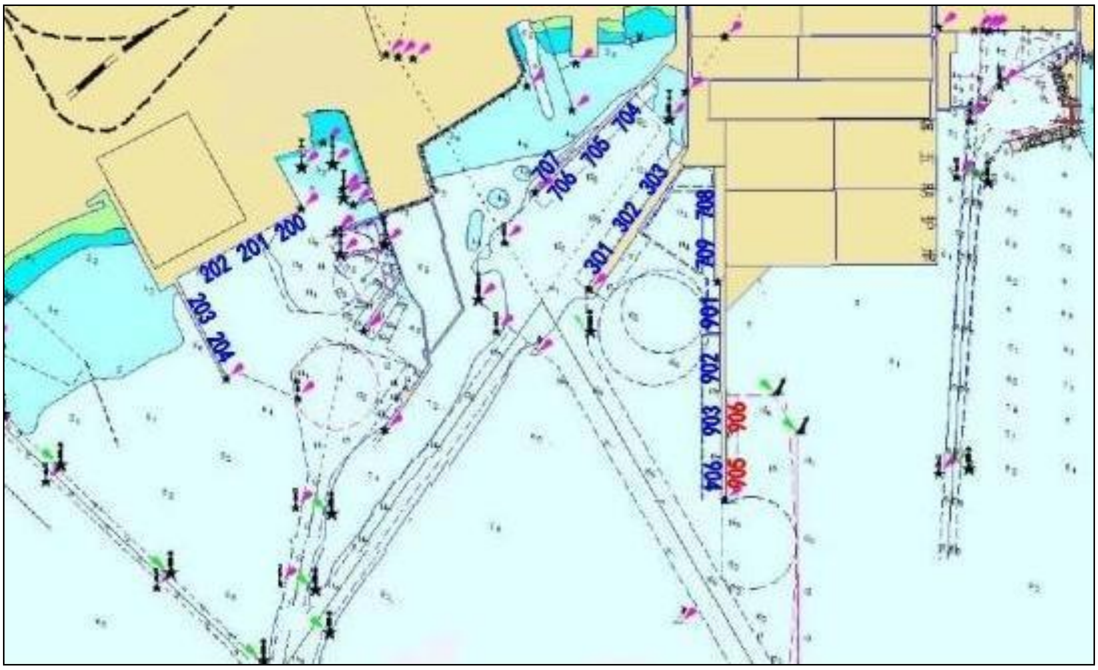


Figure 2-3 Layout of the berths for coal transportation

Source: Source: Chart 21117, (2013), China MSA.

2.1.2 Layout of the anchorages and fairways

Qinhuangdao port has five anchorages and nine fairways. The vessels using TAP are from east anchorage and west anchorage, these vessels will cross fairway 160 and fairway 150 (the fairway is named by the angle). The depths of east and west anchorage are 10.3m-17.4m and 10.3-15.7m, and the depths of fairway 150 and fairway 160 are 16.5m and 13.5m.The other anchorages and fairways are not involved.

(Hebei MSA, 2006)

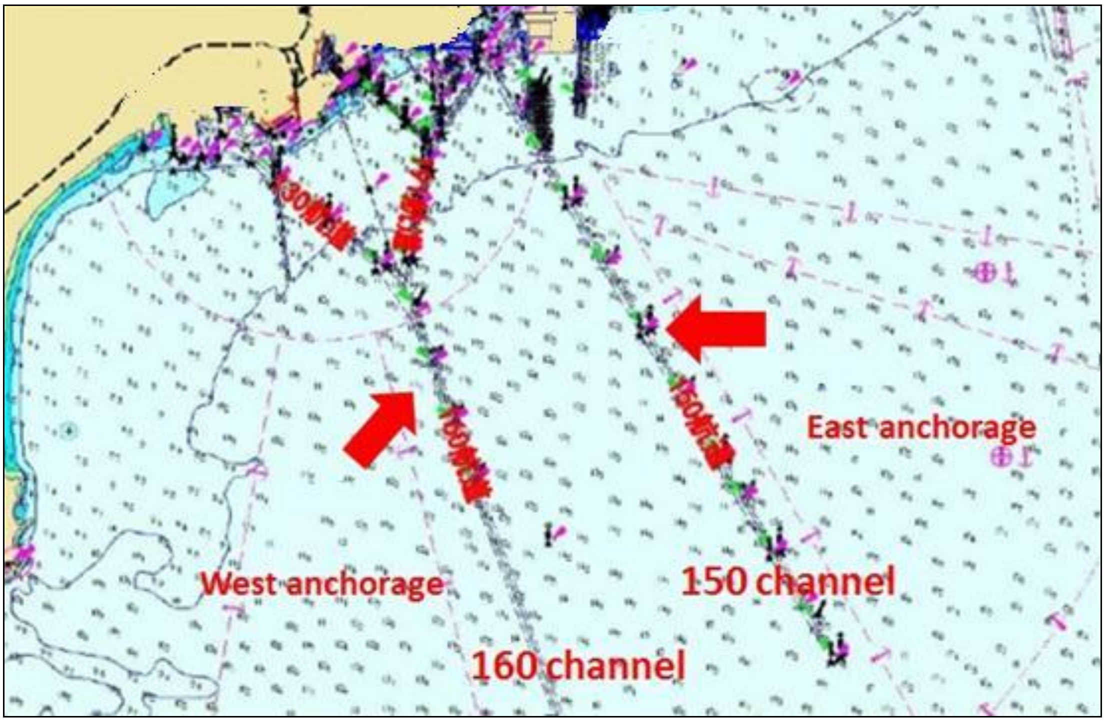


Figure 2-4 Illustration of the relevant anchorages and fairways

Source: Chart 21115, (2014), China MSA.

2.2 Traffic situation

From the Figure 2-5, the traffic flow of Qinhuangdao port is mainly on north-south direction, which consists of the tracks of the vessels' entering and leaving the port. The east-west traffic flow consists of the movements of fishing vessels, port operation vessels and other small vessels, they cross the fairways and traffic intensive area near the wharfs, also some vessels come out from the anchorage to enter the port move in the east-west direction.

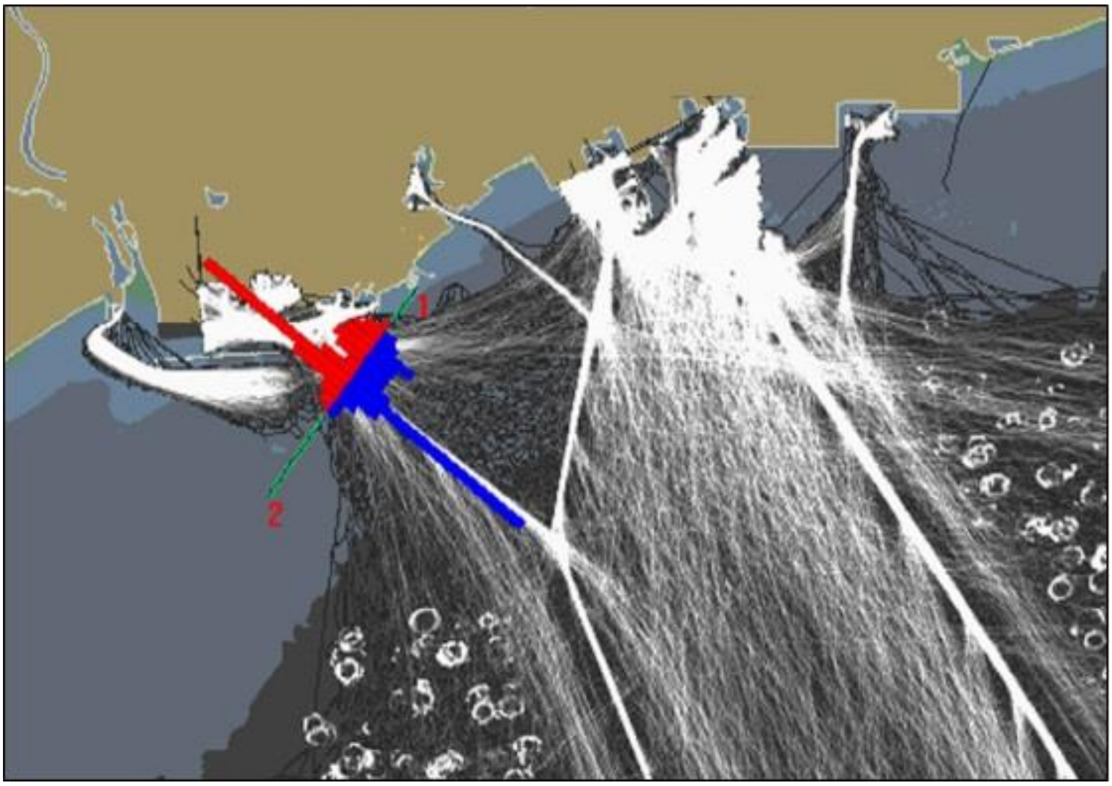


Figure 2-5 Track line of the traffic flow from AIS database in August 2013

Source: Tianjin AIS data center, (2013), Historical data.

Chapter 3 Transport efficiency for coal carriers

3.1 Introduction to port capacity and efficiency

3.1.1 Capacity of the port

The capacity of the port can be classified into designed capacity and actual capacity. Designed capacity of the port is the capacity in design project description for newly-built or expanded port. (Bruce & Wesley, 2008, pp.21-23) Designed capacity of the twenty berths for coal handling operation in Qinhuangdao port is 192.65 million tons per year. Actual capacity of the port is the capacity which has been realized through technical and management measures. The largest throughput of the twenty berths for coal handling operation is 254 million tons in 2011, so the actual capacity has exceeded the designed capacity.

3.1.2 Efficiency of the port

The efficiency of the port is the ratio of throughput and designed capacity in certain period of time. The designed capacity is a fixed value, so the bigger the throughput, the better the efficiency of the port is. As mentioned in the previous chapter, improving the transport efficiency is the key method to increase throughput.（Kuang & Chen, 2007, p.170）

3.1.3 Turnover efficiency of the port

Turnover efficiency of the port is the ratio of actual number of berthing vessels and theoretical number of vessels under designed capacity of the port. The turnover efficiency relates to the port conditions such as fairways and handling operation, it requires to reduce the vacant time of the berths. Turnover efficiency is an important criterion for the judgment of efficiency of the port. (Meng, 2012)

3.1.4 Factors affecting turnover efficiency

3.1.4.1 Port environment

The depth, width, curvature radius and tide level of fairway restrict the scale of incoming vessels. The scale, depth, sheltered condition and distance to the berths of the anchorage determine the turnover time and number of arrived vessels. The structure, depth, number and facility condition of berths directly determine the turnover efficiency and throughput of the port.

3.1.4.2 Layout of port

The layout of port can be divided into two parts: land area and water area. The layout of land area includes arrangement of berths, positions of storage. Layout of the water area focuses on the arrangement of harbor basin, turning basin, fairways and anchorages and interaction with the traffic flow. (Chen & Liao, 2009)

3.1.4.3 Natural conditions

Natural conditions like wind, rain, snow, fog, tide and temperature have great influence on port operation and they have relationship with the visibility, berthing conditions, navigation and anchoring safety.

3.1.4.4 Port authority

The factors of port authority are management and technical conditions. Management includes regulations, decision-making, management methods, personnel organization and coordination. Technical conditions not only mean the technology in the facilities, but also the ability of technological innovation.

3.2 Time structure for vessels in port

The total stay time of vessels in port can be divided into two periods: berthing time and non-berthing time. Berthing time includes cargo handling operation time, auxiliary operation time, lay-time caused by natural factors and other factors. Non-berthing time includes stay time in anchorage, time for navigation and berthing operation. (Chen, 2010)

3.2.1 Berthing time

3.2.1.1 Handling operation time

Handling operation time is calculated from the beginning of the operation until all the cargo have been loaded. This time relates to the organization of port operation, running condition of the facilities, enthusiasm of operators and workers.

3.2.1.2 Auxiliary operation time

Auxiliary operation supports the handling operation and contains the time for handling procedures, supplement of water and fuel, shifting berth, operation of the hatch cover, preparation of handling machinery. Auxiliary operation does not generate profits for the port, but it is necessary. Usually the auxiliary operation takes less than one hour before the handling operation and less than two hours after the cargo is loaded

3.2.1.3 Lay-time caused by natural factors and other factors

Lay-time caused by natural factors is the interruption caused by severe weather such as heavy rain and gale, or waiting period for vessels with deep drafts to enter the port during the time of low tide. This time could not be controlled.

Lay-time caused by other factors is the delay by some special cases which may be failures of port facilities, function loss of machinery on board, tug and pilot not reaching the designated position, discharge of ballasting water and so on. This time can be reduced unless certain cases are avoided to happen.

3.2.2 Non-berthing time

3.2.2.1 Stay time in anchorage

The main cause for the stay time in anchorage is limited berths with too many vessels. Several vessels or more have to wait to load cargo from the same berth and some vessels may wait for more than a week. Other possible reasons of staying include sanitary inspections or cargo hold cleaning operation conducted in anchorage, but these do not last long. Also some poor coordination and organization from port authority or problems on cargo supply can increase the stay time.

3.2.2.2 Time for navigation and berthing operation

This time relates to the length of fairway, ship's speed, distance between anchorage and berth, degree of familiarity with the port environment.

3.3 Data analysis of the coal carriers

3.3.1 Data of vessels arrived at port

Table 3-1 Statistics of coal carriers in 2013

Deadweight Tonnage (t)	Second branch		Sixth branch		Seventh branch		Ninth branch		Total	
	Amount	Percentage	Amount	Percentage	Amount	Percentage	Amount	Percentage	Amount	Percentage
7,000-9,999	26	1.30%	0	0%	0	0%	0	0%	26	0.33%
10,000-14,999	420	20.99%	0	0%	8	0.33%	32	1.56%	460	5.80%
15,000-19,999	761	38.03%	87	5.99%	499	20.58%	212	10.31%	1559	19.64%
20,000-24,999	348	17.39%	213	14.66%	560	23.09%	424	20.61%	1545	19.47%
25,000-29,999	190	9.50%	330	22.71%	409	16.87%	250	12.15%	1179	14.86%
30,000-49,999	116	5.80%	372	25.60%	482	19.88%	435	21.15%	1405	17.70%
50,000-69,999	126	6.30%	362	24.91%	367	15.13%	556	27.03%	1411	17.78%
70,000-99,999	14	0.70%	88	6.06%	99	4.08%	145	7.05%	346	4.36%
⩾100,000	0	0.00%	1	0.07%	1	0.04%	3	0.15%	5	0.06%
Total	2001	100.00%	1453	100.00%	2425	100.00%	2057	100.00%	7936	100.00%

Source: Qinhuangdao port authority, (2013).Historical data of Qinhuangdao port.

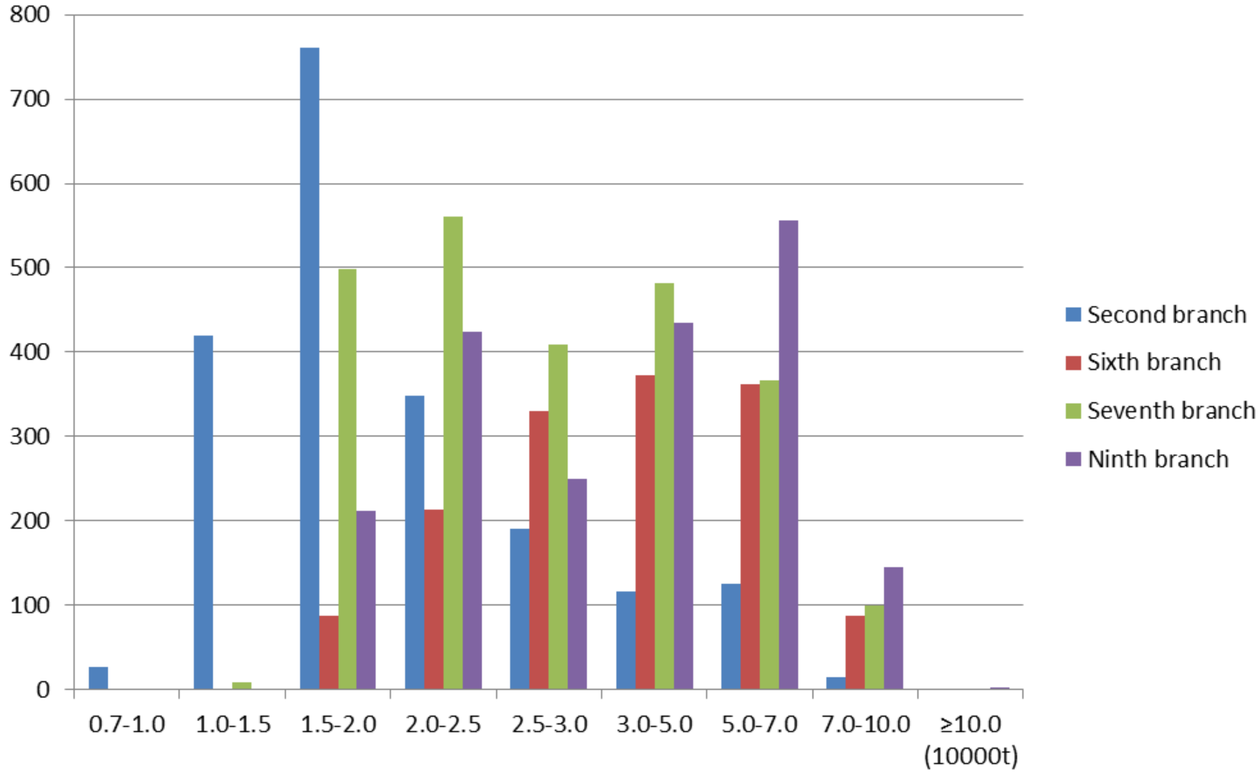


Figure 3-1 Distribution of deadweight tonnage in 2013

From Table 3-1 and Figure 3-1, the number of vessels arriving at port for these four branches is 7936 and the average number of port visit per day is 21.7. The corresponding numbers for each branch are 5.48, 3.98, 6.46 and 5.64 respectively. Because of the different capacity of the berths, the distribution of deadweight tonnage (DWT) is different. For example, the number of vessels with the DWT from 30,000t to 49,999t takes the largest proportion in sixth branch. Overall, the coal carriers focus on the DWT from 15,000t to 69,999t.

3.3.2 Statistics of non-berthing time

3.3.2.1 Time for navigation and berthing operation

The time for navigation relates to the speed and distance from the anchor position to the berth. For the sake of the convenient calculation, this section assumes vessels coming to berths of second branch anchor in the west anchorage, meanwhile vessels coming to berths of the other three branches anchor in east anchorage.

The speed of incoming vessel without cargo is 8kn. The outer boundary of east and west anchorage is 12nm, but because of the insufficient capacity of the east anchorage, some vessels anchor in the extended waters, marked in Figure 3-2. So the average distance for vessels anchoring in east anchorage is 12nm, and for west anchorage it is 8nm. The time for navigation from east and west anchorage can be calculated as 1.5h and 1h.

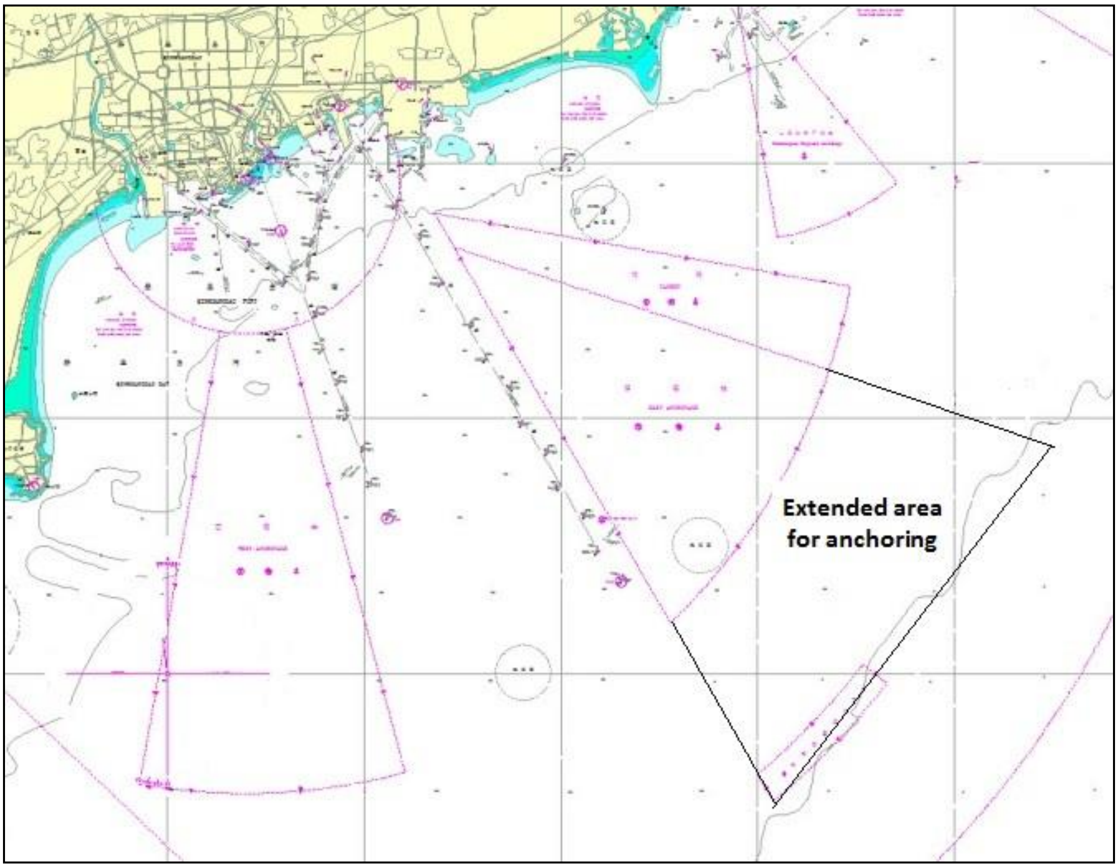
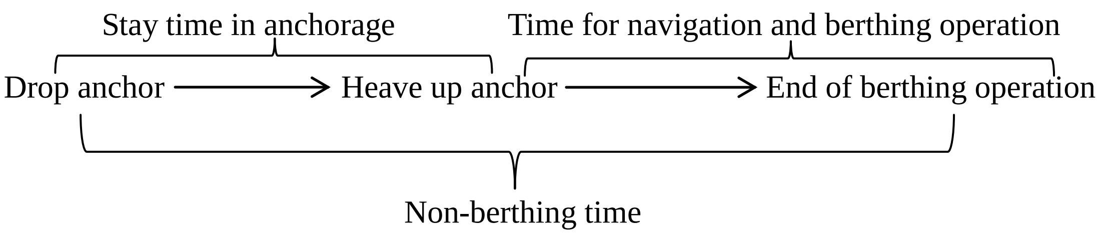


Figure 3-2 Extended area of east anchorage

Source: Chart 21001, (2011), China MSA.

Time for berthing operation depends on the degree of familiarity with the port. If there is a pilot on board, it costs about 1h. If not, the time will be 1.5-2h. The average time is 1.5h. In conclusion, the time for navigation and berthing operation from east and west anchorage are about 3h and 2.5h. For vessels coming to berths of second branch the time is about 2.5h, and the time for the other branches is about 3h.

3.3.2.2 Stay time in anchorage



Port authority records the non-berthing time, and the time for navigation and berthing operation have been worked out. Non-berthing time (T1) minus time for navigation and berthing operation (T2) is stay time in anchorage (T3).

Table 3-2 Average stay time in anchorage

DWT(t)	Second branch			Sixth branch			Seventh branch			Ninth branch		
	T1(h)	T2(h)	T3(h)	T1(h)	T2(h)	T3(h)	T1(h)	T2(h)	T3(h)	T1(h)	T2(h)	T3(h)
7,000-9,999	95.90	2.5	93.40	0	0	0	0	0	0	0	0	0
10,000-14,999	77.32	2.5	74.82	0	0	0	111.35	3	108.35	112.35	3	109.35
15,000-19,999	92.11	2.5	89.61	171.50	3	168.50	112.03	3	109.03	169.71	3	166.71
20,000-24,999	94.89	2.5	92.39	173.50	3	170.50	116.65	3	113.65	148.48	3	145.48

25,000-29,999	110.70	2.5	108.20	189.50	3	186.50	104.60	3	101.60	195.31	3	192.31
30,000-49,999	112.85	2.5	110.35	173.40	3	170.40	120.21	3	117.21	169.75	3	166.75
50,000-69,999	116.47	2.5	113.97	185.90	3	182.90	147.09	3	144.09	164.36	3	161.36
70,000-99,999	129.75	2.5	127.55	183.90	3	180.90	176.75	3	173.75	202.00	3	199
⩾100,000	0	0	0	203.70	3	200.70	138.67	3	135.67	150.28	3	147.28
Average	103.75	2.5	101.25	183.05	3	180.05	128.41	3	125.41	164.03	3	161.03

Source: Qinhuangdao port authority, (2013).Historical data of Qinhuangdao port.

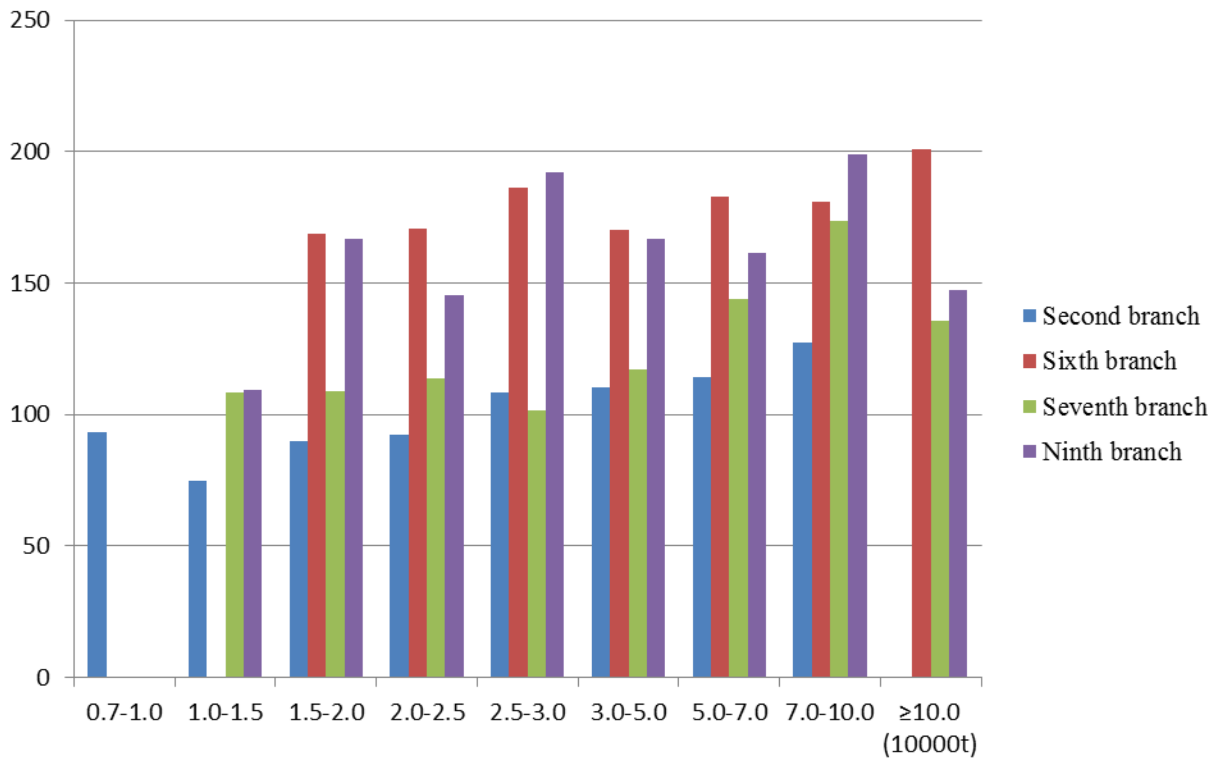


Figure 3-3 Distribution of Stay time in anchorage in 2013

From Table 3-2 and Figure 3-3, the average stay time in anchorage for four branches is 101.25h, 180.05h, 125.41h and 161.03h. The average stay time in anchorage for vessels with DWT from 70,000t to 99,999t is 170.3h, which is longest. The stay time in anchorage is too long, because the number of berths is limited, and lots of vessels wait for the same berth. This has a negative effect on the transport efficiency.

3.3.3 Statistics of berthing time

3.3.3.1 Auxiliary operation time

Before the cargo handling operation, it costs 0.5h to 1h for the operation of the hatch covers, handling procedures and adjustment of port facility. After the cargo is loaded, there still need 1h to 1.5h for topping off operation, procedures and so on. So the average time for auxiliary operation is about 2h.

3.3.3.2 Lay-time caused by natural factors and other factors

When the handling operation is not carried out, port authority records the non-effective berthing time (T4) which consists of time for auxiliary operation (T5) and lay-time caused by natural factors and other factors (T6). So T4 minus T5 is T6, they are shown in Table 3-3.

Table 3-3 Average lay-time caused by natural factors and other factors

DWT(t)	Second branch			Sixth branch			Seventh branch			Ninth branch		
	T4(h)	T5(h)	T6(h)	T4(h)	T5(h)	T6(h)	T4(h)	T5(h)	T6(h)	T4(h)	T5(h)	T6(h)
7,000-9,999	5.28	2	3.28	0	0	0	0	0	0	0	0	0
10,000-14,999	5.17	2	3.17	0	0	0	5.40	2	3.4	5.44	2	3.44
15,000-19,999	5.87	2	3.87	4.03	2	2.03	5.01	2	3.01	6.20	2	4.2
20,000-24,999	6.85	2	4.85	3.48	2	1.48	5.01	2	3.01	6.56	2	4.56
25,000-29,999	6.79	2	4.79	3.62	2	1.62	4.73	2	2.73	6.13	2	4.13

30,000-49,999	5.2	2	3.2	3.74	2	1.74	5.31	2	3.31	4.25	2	2.25
50,000-69,999	5.4	2	3.4	5.91	2	3.91	4.74	2	2.74	4.79	2	2.79
70,000-99,999	5	2	3	6.81	2	4.81	6.94	2	4.94	5.31	2	3.31
⩾100,000	0	0	0	5	2	3	6.15	2	4.15	3.83	2	1.83
Average	5.2	2	3.2	4.97	2	2.97	5.2	2	3.2	5.31	2	3.31

Source: Qinhuangdao port authority, (2013).Historical data of Qinhuangdao port.

From Table 3-3, the average lay-time for four branches are 3.2h, 2.97h, 3.2h and 3.31h, the difference between the branches is minor. This time take up small proportion in the whole time period of transport process.

3.3.3.3 Handling operation time

Table 3-4 Handling operation time

DWT(t)	Second branch		Sixth branch		Seventh branch		Ninth branch	
	Amount	Average time (h)	Amount	Average time (h)	Amount	Average time (h)	Amount	Average time (h)
7,000-9,999	26	8.21	0	0	0	0	0	0
10,000-14,999	420	8.74	0	0	8	7.18	32	10.94
15,000-19,999	761	10.64	87	6.28	499	8.08	212	7.81
20,000-24,999	348	11.64	213	7.64	560	9.38	424	10.39
25,000-29,999	190	13.65	330	8.53	409	12.13	250	12.02
30,000-49,999	116	15.46	372	11.77	482	14.94	435	15.93
50,000-69,999	126	19.61	362	13.84	367	19.71	556	18.89
70,000-99,999	14	15.97	88	13.96	99	22.94	145	20.64
⩾100,000	0	0	1	19.83	1	27.83	3	24.89
Average	2001	12.99	1453	11.69	2425	15.27	2057	15.19

Source: Qinhuangdao port authority, (2013).Historical data of Qinhuangdao port.

From Table 3-4, the handling operation time increases with the DWT. At present, the degree of mechanization for handling operation is very high, as the handling facilities are advanced, and there are little space to make improvement.

3.4 Efficiency analysis of the coal carriers

3.4.1 Time distribution for vessels in port

As mentioned in pervious sections, time in port for vessels consists of five time periods, the result of distribution for different time periods is shown in Table 3-5.

Table 3-5 Time distribution in port

Time period	Second branch		Sixth branch		Seventh branch		Ninth branch	
	Average	percentage	Average	percentage	Average	percentage	Average	percentage
Stay time in anchorage (h)	101.25	83.03%	180.05	90.16%	125.41	84.24%	161.03	87.26%
Time for navigation and berthing operation (h)	2.50	2.05%	3.00	1.50%	3.00	2.02%	3.00	1.63%
Handling operation time (h)	12.99	10.65%	11.69	5.85%	15.27	10.26%	15.19	8.24%
Auxiliary operation time (h)	2.00	1.64%	2.00	1.00%	2.00	1.34%	2.00	1.08%
Lay-time caused by natural factors and other factors (h)	3.20	2.63%	2.97	1.49%	3.20	2.14%	3.31	1.79%
Average time in port (h)	121.94	100.00	199.71	100.00	148.88	100.00	184.53	100.00

Source: Qinhuangdao port authority, (2013).Historical data of Qinhuangdao port.

From the time distribution, stay time in anchorage takes up the largest proportion which is several times larger than the total of other four factors. Handling operation takes the second place, and the other three factors take up a small portion.

3.4.2 Time distribution of berthing time

In berthing time, handling operation time is effective berthing time. Auxiliary operation time, lay-time caused by natural factors and other factors are non-effective berthing time. Based on the data from Table 3-3 and Table 3-4, the effective berthing time and non-effective berthing time can be worked out.

Table 3-6 Time distribution of berthing time

Items	Second branch	Sixth branch	Seventh branch	Ninth branch	Total
Number of the berths	5	3	6	6	20
Total berthing time in actual situation(h)	36,398.2	24,207.0	49,639.8	42,168.5	152,413.5
Average berthing time in actual situation (h)	7279.6	8069.0	8273.3	7028.1	30650.0
Average effective berthing time (h)	5198.6	5661.8	6171.6	5207.6	22239.6
Average non-effective berthing time (h)	2081.0	2407.1	2101.7	1820.5	8410.2
Average total berthing time in theory (h)	8760.0	8760.0	8760.0	8760.0	8760.0
Average vacant time (h)	1480.4	691.1	486.7	1731.9	4390.0

Source: Qinhuangdao port authority, (2013).Historical data of Qinhuangdao port.

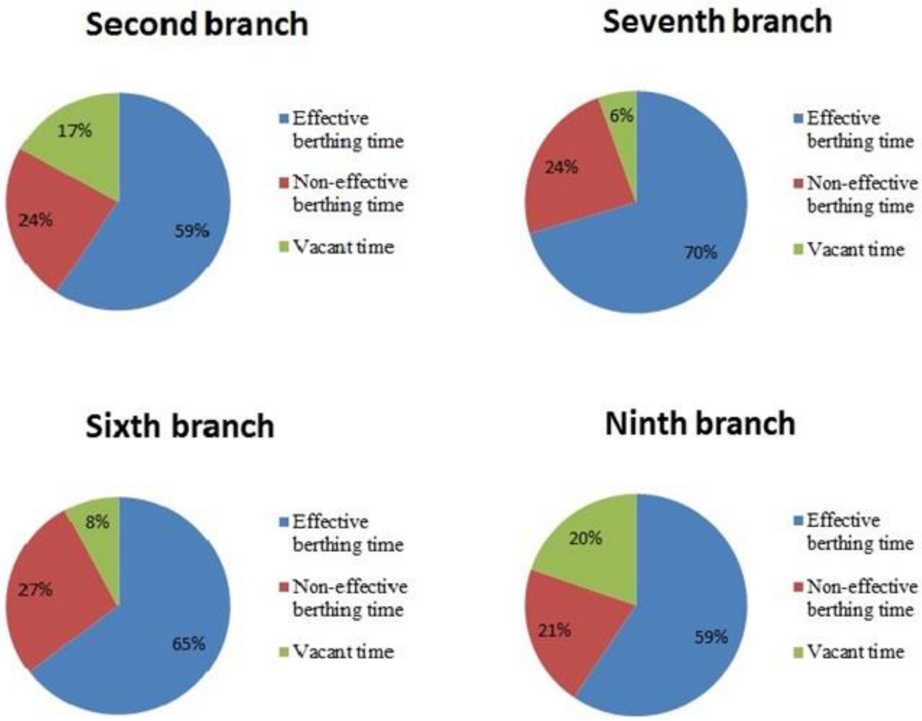


Figure 3-4 Time distribution of berthing time

Overall, effective time takes largest proportion in berthing time. But there are still vacant time and non-effective time which are the points for improving the efficiency of the port. Vacant time relates to turnover efficiency of vessels which means the incoming vessels do not come to the berth in time. Non-effective berthing time relates to the operation efficiency on berth, preparation for handling operation or other factors leading to delay of handling operation.

3.4.3 Comparison between berthing time and stay time in anchorage

Table 3-7 Average berthing time (T7) and stay time in anchorage (T8)

DWT(t)	Second branch			Sixth branch			Seventh branch			Ninth branch		
	T7(h)	T8(h)	Ratio	T7(h)	T8(h)	Ratio	T7(h)	T8(h)	Ratio	T7(h)	T8(h)	Ratio
7,000-9,999	13.49	93.40	0.14	0	0	0	0	0	0	0	0	0

10,000-14,999	13.91	74.82	0.19	0	0	0	12.58	108.35	0.12	16.38	109.35	0.15
15,000-19,999	16.51	89.61	0.18	10.31	168.50	0.06	13.09	109.03	0.12	14.01	166.71	0.08
20,000-24,999	18.49	92.39	0.20	11.12	170.50	0.06	14.39	113.65	0.13	16.95	145.48	0.12
25,000-29,999	20.44	108.20	0.19	12.15	186.50	0.06	16.86	101.60	0.16	18.15	192.31	0.09
30,000-49,999	20.66	110.35	0.19	15.51	170.40	0.09	20.25	117.21	0.17	20.18	166.75	0.12
50,000-69,999	25.01	113.97	0.22	19.75	182.90	0.11	24.45	144.09	0.17	23.68	161.36	0.15
70,000-99,999	20.97	127.55	0.16	20.77	180.90	0.11	29.88	173.75	0.17	25.95	199.00	0.13
⩾100,000	0	0	0	24.83	200.70	0.12	33.98	135.67	0.25	28.72	147.28	0.19
Total	18.19	101.25	0.18	16.66	180.05	0.09	20.47	125.41	0.16	20.50	161.03	0.13

Source: Qinhuangdao port authority, (2013).Historical data of Qinhuangdao port.

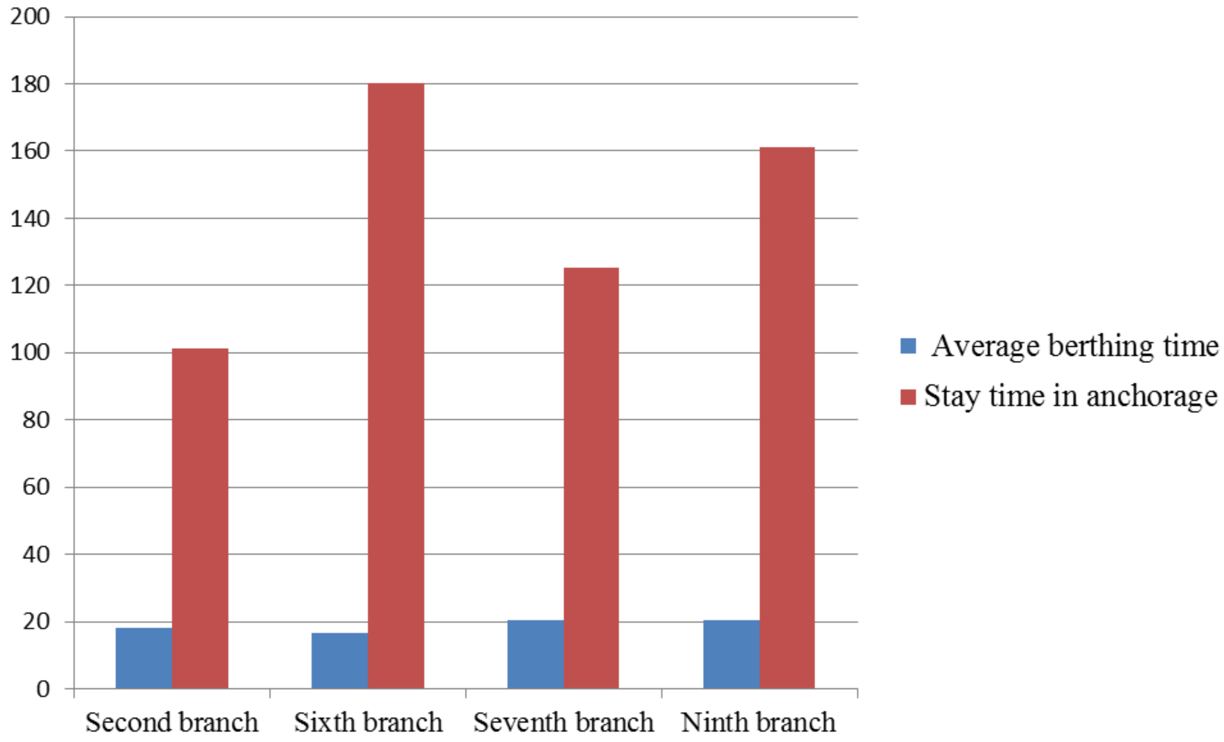


Figure 3-5 Comparison between berthing time and stay time in anchorage

The comparison between berthing time and stay time in anchorage can show the turnover efficiency of the port which is quite low for these four branches. The phenomenon for vessels waiting for the same berth is quite common, and due to the insufficient berths, it has quite negative effect on transport efficiency.

3.5 Measures for improvements of the transport efficiency

Statistical data show that among many factors that affect the transport efficiency, some can be adjusted while some cannot be controlled. According to the actual situation of Qinhuangdao port, some measures are put forward in Table 3-7.

Table 3-8 Measures and effects for improvements of the transport efficiency

<table>
<tr><th colspan="2">Factors</th><th>Measures</th><th>Relevant time periods</th><th>Results</th><th>Investment</th></tr>
<tr><td rowspan="4">Port conditions</td><td>Berths</td><td>Increase the number of berths</td><td>Stay time in anchorage</td><td>Remarkable effect</td><td>Large investment</td></tr>
<tr><td>Handling facility</td><td>Add handling facility</td><td>Handling operation time</td><td>Remarkable effect</td><td>Large investment</td></tr>
<tr><td>Fairway</td><td>Expand the fairway to two-way traffic</td><td>Navigation period</td><td>Remarkable effect</td><td>Large investment</td></tr>
<tr><td>Tug</td><td>Increase the number of tugs</td><td>Berthing operation</td><td>Certain effect</td><td>Large investment</td></tr>
<tr><td rowspan="3">Vessels conditions</td><td>Balast water</td><td>Discharge the balast water in advance</td><td>Handling operation time</td><td>Certain effect</td><td>No investment</td></tr>
<tr><td>Maneuvering equipment</td><td>Improve reliability of maneuvering equipment</td><td>Navigation period</td><td>Certain effect</td><td>No investment</td></tr>
<tr><td>Handling equipment</td><td>Make preparation in advance</td><td>Auxiliary operation</td><td>Certain effect</td><td>No investment</td></tr>
<tr><td rowspan="3">Management of port authority</td><td>Quality of personnel</td><td>Improve enthusiasm of personnel</td><td rowspan="3">Berthing time</td><td>Certain effect</td><td>Small investment</td></tr>
<tr><td>Technical conditions</td><td>Introduce advanced faciclities with high reliability</td><td>Certain effect</td><td>Small investment</td></tr>
<tr><td>Standard of management</td><td>Enhance the level of enterprise management</td><td>Certain effect</td><td>Small investment</td></tr>
<tr><td rowspan="4">Traffic conditions</td><td>Entry plan</td><td>Arrange the entry plan reasonably</td><td rowspan="4">Berthing time and stay time in the anchaorage</td><td>Remarkable effect</td><td>Small investment</td></tr>
<tr><td>Navigation</td><td>Set up temporary anchor positions</td><td>Remarkable effect</td><td>Small investment</td></tr>
<tr><td>Dynamic information</td><td>Strengthen information communication</td><td>Remarkable effect</td><td>Small investment</td></tr>
<tr><td>Trffic organization</td><td>Scientific organizations of traffic</td><td>Remarkable effect</td><td>Small investment</td></tr>
</table>

Source: compiled by author. (2014)

In current circumstances, measures which have certain effect cannot bring fundamental improvement to the transport efficiency of Qinhuangdao port. Measures with large investment need further assessment to prove whether they are feasible or not. Setting up temporary anchor positions is a method which needs small investment. Meanwhile Qinhuangdao VTS has relevant experience for incoming vessels waiting alongside the fairway, so it has practical experience to some extent.

Chapter 4 Selecting and analysis of temporary anchor positions

4.1 Introduction to temporary anchor positions

4.1.1 The aim of selecting of TAP

As mentioned, the stay time in anchorage relates to the limited berths, and it is impossible to change the situation in a short period. Handling operation and auxiliary operation leave less space for improvement due to the maturity of the technological condition. Lay time is caused by other factors which cannot be controlled. Time in berthing operation has been reduced to the bottom. TAP could be introduced to save the time for navigation and reduce the vacant time for berths which is equivalent to shorten the distance between anchor positions and berths.

4.1.2 The requirements for the selecting of TAP

TAP locates in the waters near the port, it belongs to the scope of inner anchorage, it must comply with the requirements of *Code for Design of General Layout of Sea Ports* (Code for short).

4.1.2.1 Ship type

According to design dimension of ships in *Code*, the particulars of coal carriers are determined in Table 4-1.

Table 4-1 Ship type

DWT(t)	Overall length (m)	Molded breadth (m)	Molded depth (m)	Load draught (m)	Ballast draft (m)	Maximum ballast draft (m)
35,000	190	30.4	15.8	11.2	7.14	7.48
50,000	223	32.3	17.9	12.8	7.20	7.68
70,000	228	32.3	19.6	14.2	7.43	8.42
100,000	250	43.0	20.3	14.5	--	--

According to the historical data, number of vessels with DWT larger than 70000t is small. This section chooses vessels whose DWT is smaller than 70000t to be the basis of selecting of TAP.

4.1.2.2 Requirements on depth

The article 4 of Code stipulates: "*the depth of the anchorage should be 1.2 times of the load draught in design type*".

Table 4-2 Required depth of the TAP

DWT(t)	Overall length (m)	Molded breadth (m)	Molded depth (m)	Ballast draft (m)	Required depth (m)
35,000	190	30.4	15.8	7.14	8,57
50,000	223	32.3	17.9	7.20	8.64
70,000	228	32.3	19.6	7.43	8.92

4.1.2.3 Scale of TAP

(1) The area of single anchor position

The article 4 of the Code stipulates: "*the area of each anchor position shoule be the area of circle"*, the radius is calculated according to the following formula.

When the wind force is weaker than near gale (7 grade): $R = L + 3H + 90$

When the wind force is stronger than near gale (7 grade): $R = L + 4H + 145$

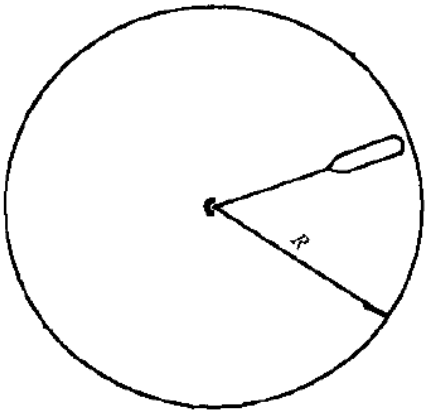


Figure 4-1 Area of single anchor position

Source: Code for Design of General Layout of Sea Ports

R: the radius of the anchoring circle (m)

L: overall length, take the overall length of vessel with DWT 70000t, 228m

H: depth of anchor position, take the result in Table 4-2, 9m

When the wind force is weaker than near gale, the radius is 345m. Considering the safety reserve distance, the radius is assumed as 400m.

(2) The number of single anchor position

According to the stipulation of the Code, when the berth utilization reach 70%, the twenty berths for coal transportation need 8-9 anchor positions. In fact, only the vessels in the entry plan from the port authority can use the anchor position, meanwhile the water area is limited, so the scale for 3-4 anchor positions is feasible.

4.1.2.4 Safe distance between TAP and fairway

The article 4 of the Code stipulates: "*the distance between inner anchorage and fairway should not be lese than overall length".* The maxmium overall length is 228m (vessels with DWT 70,000t), so the safe distance should be 230m at least.

4.1.2.5 Other requirements on TAP

The code stipulates that the anchor position must keep away from rocks and shoals, and it should be less influenced by wind, wave and current. The sea bottom should be a mixture of soil and sand. The natural conditions of Qinhuangdao port meet all the requirements except that the shelter condition from wind is not ideal. The natural conditions cannot provide shelter for southwest and northeast wind. But TAP is near the port, the influence is much less than five existing anchorage. (Zhang, 2012)

4.2 The selecting of temporary anchor positions

4.2.1 Location selection

4.2.1.1 Locations

The location is selected in area which is 2.5nm away from the berths of the four branches. There are three plans shown in Figure 4-2

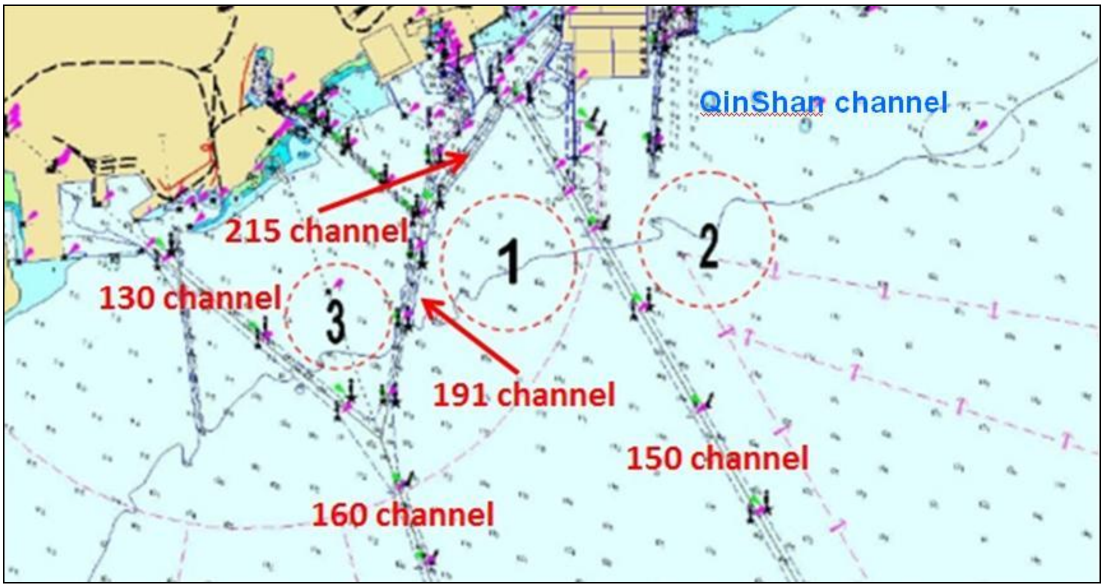


Figure 4-2 Locations of TAP

Source: Chart 21115, (2014), China MSA.

Location 1: it is located in the west of fairway 150 and east of fairway 191, depth contour of 10m cross its area.

Location 2: it is located in the east of fairway 150 and overlaps with tanker anchorage, depth contour of 10m cross its area.

Location 3: it is located in the west of fairway 191 and east of fairway 130, most of the area is in the north of the depth contour of 10m.

4.2.1.2 Comparison of locations

Table 4-3 Comparison of locations

Items	Location 1	Location 2	Location 3
Distance to the berths	＜2nmile	Maximum distance is 2.7nmile	Maximum distance is 2.7nmile
Impact on the navigable waters	Minor impact (Less occupation on navigable waters)	Great impact(Occupy the navigable waters of Qinshan fairway)	General impact (Impact on the visibility of leading mark for fairway 160)

Enter from east anchorage	Cross fairway 150	No impact	Cross fairway 150 and 191
Enter from west anchorage	Cross fairway 160	Cross fairway 150 and 160	Cross fairway 130
Depth	8.5～10m	8.5~11m	9.3~12m
Scale	Bigger	Bigger	Smaller

Source: compiled by author. (2014)

After the comprehensive comparison, location 1 has more advantages than other plans, it is the best choice.

4.2.2 The layout plan

The distance from TAP to the fairway should be 230m at least. The fairway 191, fairway 150 and fairway 215 constitute the boundary of TAP in three directions, the southern boundary depends on the layout of the TAP

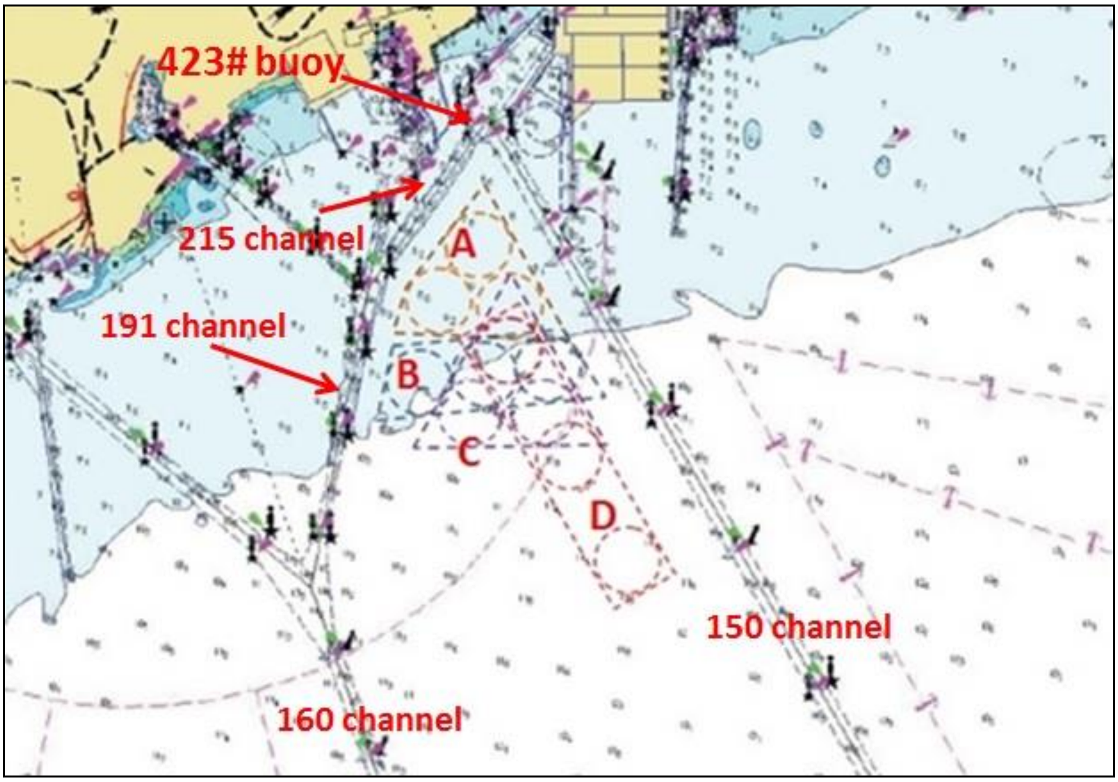


Figure 4-3 Layout plan of TAP

Source: Chart 21115, (2014), China MSA.

Plan A: The boundary of three TAP is arranged as a triangle, the distances from boundary to the fairway 150, fairway 215 and 423# buoy are 280m, 260m and 800m.

Plan B: Three TAP are arranged in a line, the distances from boundary to the fairway 150, fairway 191 and 423# buoy are 280m, 260m and 2200m.

Plan C: The boundary of three TAP is arranged as a triangle, the distances from boundary to the fairway 150, fairway 215 and 423# buoy are 500m, 600m and 1800m.

Plan D: the boundary of three TAP is arranged as a rectangle, the anchoring circles are 600m apart. The distances from boundary to the fairway 150, fairway 215 and 423# buoy are 500m, 1100m and 1800m.

4.2.3 Selection of layout plan

4.2.3.1 Depth

Plan A: Three anchor positions are located in the north of depth contour of 10m. The depth of the north anchor position is 8.0m-8.7m, it cannot meet the requirement of anchoring for 35,000t vessels with ballast water (8.57m). The depth of two anchor positions in south is 8.6m-9.4m, it can meet the requirement of anchoring for 50,000t vessels with ballast water (8.64m).

Plan B: Three anchor positions cross the contour of 10m, the depth is 9.5m-10.6m, it meets the requirement of anchoring for 70,000t vessels with ballast water (8.92m).

Plan C: The north anchor position crosses the depth contour of 10m, the depth is 9.5m-10.3m. Two anchor positions in south are located in the south of depth contour of 10m, the depth is 10.2m-11.0m. It meets the requirement of anchoring for 70,000t vessels with ballast water (8.92m).

Plan D: The north anchor position crosses the depth contour of 10m, the depth is 9.5m-10.3m. Two anchor positions in south are located in the south of depth contour of 10m, the depth is 11.3m-11.7m. It meets the requirement of anchoring for 70,000t vessels with ballast water (8.92m).

Table 4-4 Depth of the layout plan

Layout plan		Depth(m)	Required depth for vessels with ballast water(m)		
			35,000t	50,000t	70,000t
Plan A	North	8.0～8.7	8.57	8.64	8.92
	West one in south	8.6～9.3			
	East one in south	8.7～9.4			
Plan B	West	9.5～10.0			
	Middle	9.5～10.3			
	East	9.7~10.6			
Plan C	North	9.5～10.3			
	West one in south	10.2～10.7			
	East one in south	10.3~11.0			
Plan D	North	9.5～10.3			
	Middle	11.3			
	South	11.7			

Source: Chart 21115,Chart 21117, Chart 20106B，(2014), China MSA.

From the angle of depth, the north anchor position in plan A does not meet the requirement. Plan B, plan C and plan D can be adopted.

4.2.3.2 Impact on traffic environment

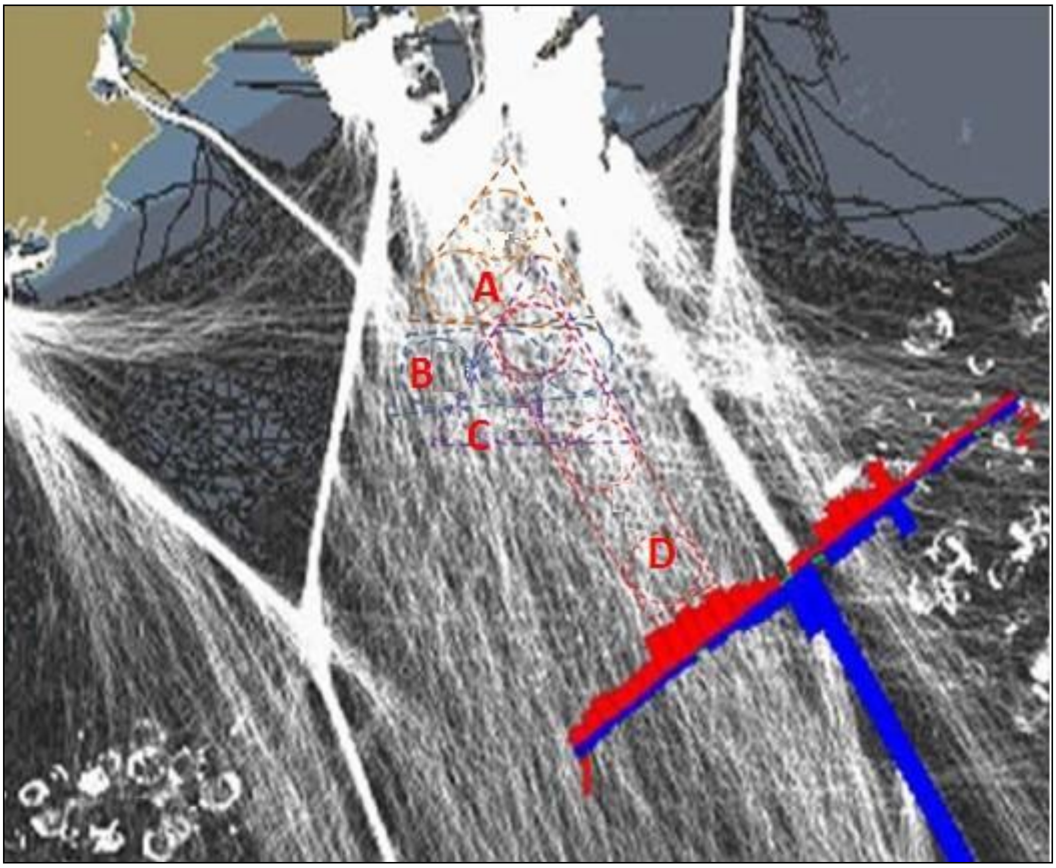


Figure 4-4 Track line of the traffic flow from AIS database in August 2013

Source: Tianjin AIS data center, (2013), Historical data.

From Figure 4-4, the traffic flow is mainly on north-south direction, it focuses on the fairway 150 and fairway 191, and it consists of the tracks of the vessels' entering and leaving the port. The incoming vessels with small draft choose to enter the fairway from the buoy close to the port, the leaving vessels get off the fairway when the depth out of the fairway is deeper than the draft. The east-west traffic flow is mainly on the movements of fishing vessels, port operation vessels and other small vessels.

The traffic flow in north-south direction is most dense in plan A while plan D has minimal impact, the impact of plan B and plan C are moderate. The traffic flow in east-west direction is the most dense in plan B, the other three plans are moderate. Plan D has an advantage that it leaves more space between anchor positions for the vessels to pass through.

4.2.3.3 Natural conditions

Except the bad shelter condition for wind introduced in chapter 4.1.2.5, the jetty of ninth branch is against to the current. The current in the south of the jetty is strong due to the block affect. Plan A appears most affected while plan D is not affected much. Plan B and plan C are moderately affected.

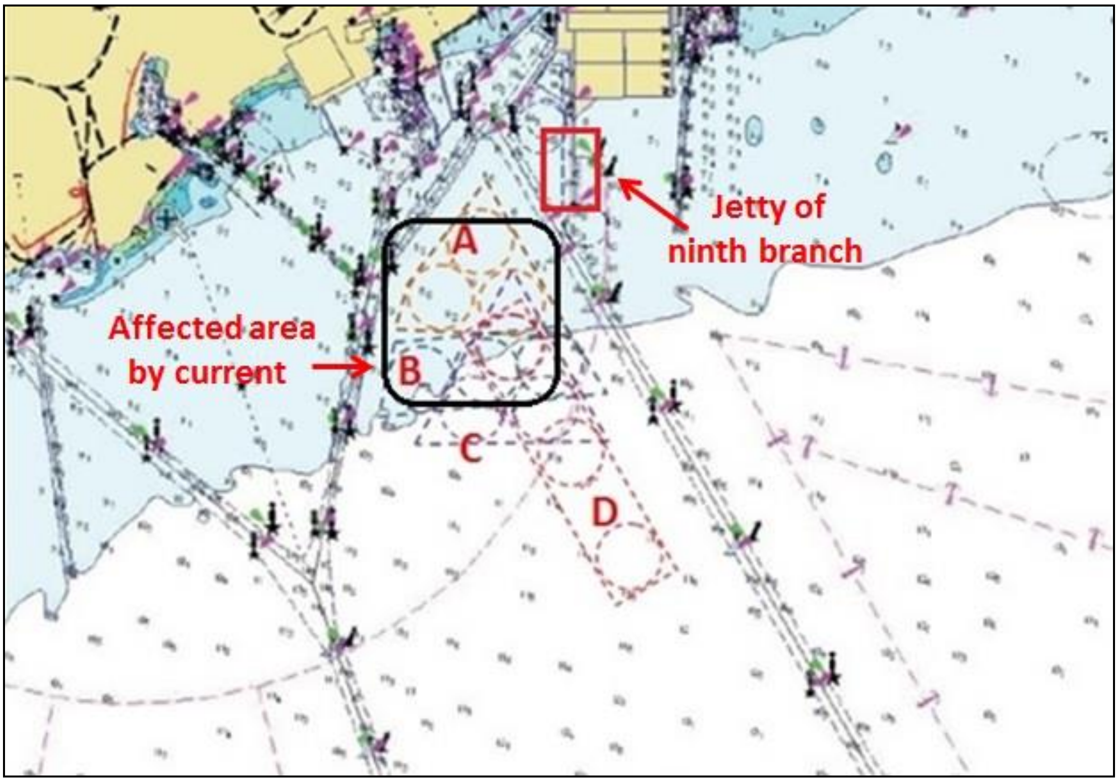


Figure 4-5 Affected area by current

Source: Chart 21115, (2014), China MSA.

4.2.3.4 Comparison of layout plan

Table 4-5 Comparison of layout plan

Item	Plan A	Plan B	Plan C	Plan D
Distance to berths	Nearest	Moderate	Farther	Farther
The closest distance to fairway	280m	280m	500m	500m
Depth	8.0～9.4m	9.5～10.6m	9.5～11.0m	9.5～11.7m
Applicable vessel	≤35,000t	≤70,000t	≤70,000t	≤70,000t
Number of the effective anchor position	2	3	3	3
Space for vessels to passing through	Small	Small	Small	Big
Investment	Large investment(dredging operation and depth survey are required)	Small investment (depth survey is required)	Small investment (depth survey is required)	Small investment (depth survey is required)
Traffic density in east-west direction	Low	High	Low	Low
Traffic density in north-south direction	High	High	Moderate	Moderate

Source: compiled by author. (2014)

From Table 4-5, plan D is optimal choice compared with all the items.

4.3 Limitation of using temporary anchor positions

4.3.1 Limitation on draft

Table 4-6 Limitation on draft

Temporary anchor position		Depth(m)	Permitted maximum draft(m)
Plan D	North	9.5-10.3	7.9
	Middle	11.3	9.4
	South	11.7	9.7

Source: Chart 21115,Chart 21117, Chart 20106B，(2014), China MSA.

In previous sections, the required depth of TAP bases on ballast draft, but vessels have maximum ballast draft (Table 4-1). The depth of the anchorage should be 1.2

times of the load draught in design type. The maximum ballast draft of vessels with DWT 70,000t is 8.42m, depth of the TAP needs to be 10.1m. The north anchor position in plan D does not meet the requirement, but maximum ballast draft rarely appears. So the depth can still be treated as conforming to draft of vessels with DWT 70,000t, but more attention should be paid to check the ballast draft.

4.3.2 Limitation on minimum chain length

The area taken by anchoring vessel not only relates to the wind and currents, but also has close relation with the chain length (S).(Source: Code for Design of General Layout of Sea Ports)

$$R = x_0 + L$$

R: radius of the anchoring circle

x_0 : distance from position of the anchor to hawsehole

L: overall length of vessel

Generally speaking, x_0 is replaced by the S. The result is bigger than the actual radius of the anchoring circle, it complies with the safety requirements.

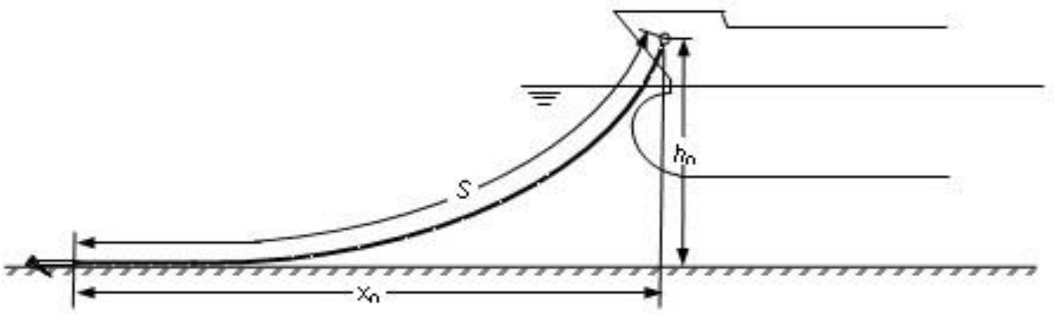


Figure 4-6 Illustration of the chain length

Source: Code for Design of General Layout of Sea Ports

Table 4-7 Radius of the anchoring circle

DWT(t) and L	Radius of the anchoring circle			
	S=110m	S=137.5m	S=165m	S=192.5m
35,000t (L=190m)	300m	327.5m	355m	382.5m
50,000t (L=223m)	333m	360.5m	388m	415.5m
70,000t (L=228m)	338m	365.5m	393m	420.5m

Source: Code for Design of General Layout of Sea Ports

In chapter 4.1.2.3, the radius is assumed as 400m, when the chain length is 165m, the radius is close to 400m. Considering the traffic density near the TAP, the chain length should not be longer than 137.5m.

4.3.3 Limitation from natural conditions

4.3.3.1 Limitation on wind

The calculation for radius of TAP is based on the requirement of the Code which is for the heavy load vessel, and the wind force is weaker than near gale. But TAP is for vessels with ballast water whose windward area is much larger than heavy load vessels which are more easily affected by wind. Meanwhile the maximum chain length is 5 shackles, and wind resistant ability of vessels using TAP is limited. According to the actual situation of Qinhuangdao port, TAP should be not be used when the wind force is stronger than strong breeze.

4.3.3.2 Limitation on waves

The wave height of TAP is lower than east and west anchorage, but range of sway for vessels with ballast water is larger than heavy load vessels, and increment of draft is much larger. According to the Code, when 4% of wave height is higher than 2m in anchorage, extra quantity on depth should be increased. Except for storm tide and typhoon, 4% of wave height is lower than 2m in TAP. Considering the sway of vessels with ballast water, 4% of wave height in TAP should be lower than 1.5m.

4.3.3.3 Limitation on current

As mentioned in chapter 4.2.3.3, the opposition of the jetty generates the current in TAP, and its speed may be more than 1kn. But vessels with ballast water are less affected than heavy load vessels. According to the experiences, if the speed of the current is less than 2kn, the vessels are safe with 5 shackles in water.

4.3.3.4 Limitation on tide

The average lowest tide is 0.51m in Qinhuangdao port, in general the actual depth of the TAP is larger than the depth on chart. If the tide is not lower than 0m, the depth of TAP conforms to the requirement of the vessels with ballast water. But there used to be tide which is -1.43m in winter, extreme case must not be neglected.

4.3.3.5 Limitation on sea ice

In January and February, there are lots of ices in sea area of Qinhuangdao port. When the ice moves with the flow, it will generate great force which resists the movement of vessels. Dragging of anchor, break of chain and unable to move may happen to vessels. TAP is much closer to the land than anchorage, so the impact caused by ice is more serious. So use of TAP should be careful on ice period.

4.3.4 Limitation on anchoring time and standby engine

In general, the entry plan from port authority does not have great adjustment in twelve hours. In order to reduce the waiting time in TAP, considering the navigation time, vessels in east and west anchorage should be allowed to move into TAP three hours ahead. If the entry plan changes, the vessels are permitted to wait in the TAP for six hours. When the waiting time will be longer than twelve hours, the vessels should come back to the anchorage.

Due to the dense traffic, vessels in TAP should be ready to avoid accidents. Meanwhile the vessels should always be ready to enter the port, so the engine need be standby constantly.

4.3.5 Detection for the TAP area

Many vessels pass through the area of TAP, but no vessels anchor here. Before the TAP is used, sweeping survey is required to ensure no shallow point in the area. Bottom detection is also necessary, and obstructions must be found out and clear.

4.4 Efficiency analysis of temporary anchor positions

4.4.1 Estimation methods

The vacant time (Δt) saved by each TAP per day can be estimated by following formula (Source: Code for Port Engineering Technology):

$$\Delta t = \frac{\Delta L}{V_s} \times \frac{24 - \Delta t_2}{\Delta t_1}$$

ΔL :distance taken by the heavy load vessels on the fairway (nm)；

V_s: speed of the incoming vessels (kn)；

Δt_1: average taken time for each TPA per day

Δt_2: average vacant time for each TPA per day.

The efficiency of each berth (ΔM) improved by each TAP can be estimated by following formula (Source: Code for Port Engineering Technology):

$$\Delta M = \frac{\Delta t}{n} \times \frac{100}{\Delta T}$$

n: number of the berths;

ΔT: berthing time per day.

4.4.2 Parameter value

4.4.2.1 Distance taken by the heavy loaded vessels in the fairway

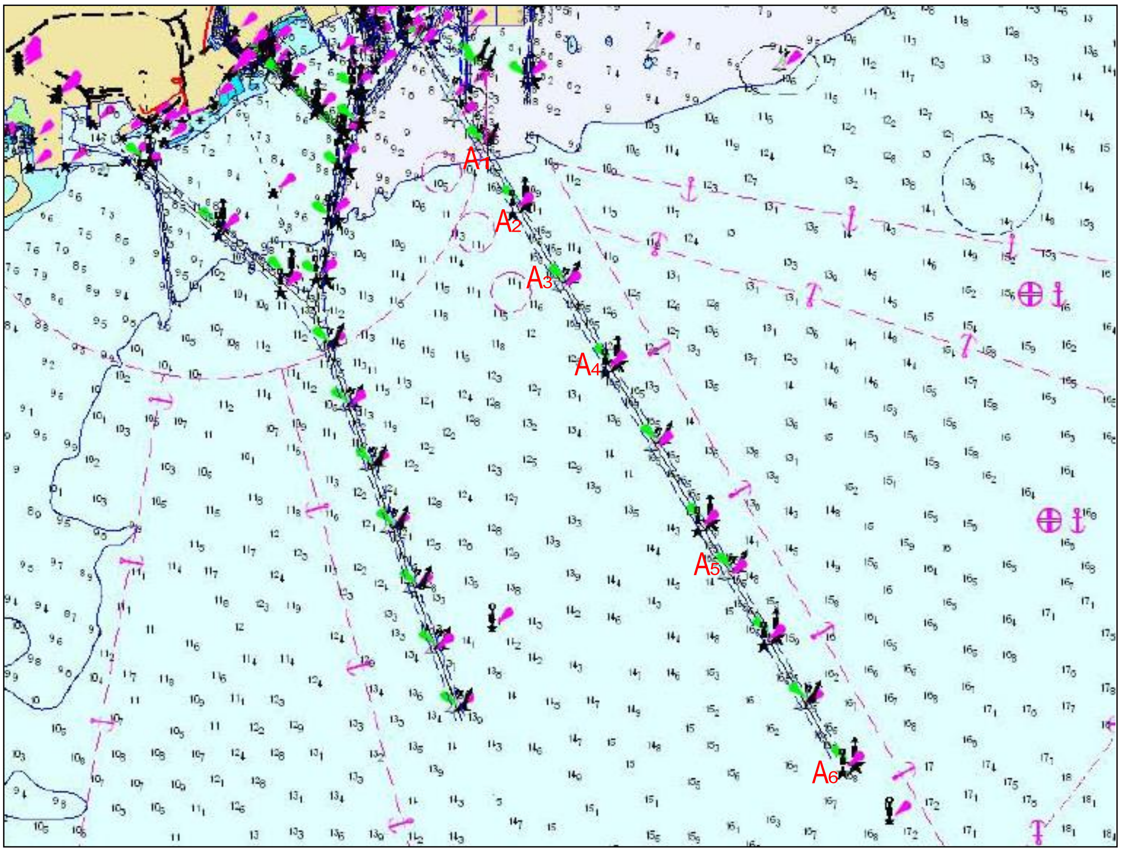


Figure 4-7 Reference point on fairway 150

Source: Chart 21115, (2014), China MSA.

Take fairway 150 for example, A_1, A_2 and A_3 are intersections between vertical line from three temporary anchor positions and fairway. When the leaving vessels pass A_1, A_2 and A_3, vessels in TAP are permitted to enter the fairway. Without TAP, A_4 is the closest position for incoming vessels to enter the fairway, A_6 is the farthest position. A_5 is the middle position of A_4 and A_6. When TAP is implemented, the saved time for vacant berths is navigation time on fairway between A_1, A_2, A_3 and A_4, A_5, A_6.

From the formula, ΔL (distance taken by the heavy load vessels on the fairway)is proportional to Δt. So if incoming vessels enter the fairway from A_6, ΔL is the biggest, the saved time is most. The saved time is least for A_4. But vessels in east anchorage cannot focus on areas near A_4 or A_6, so A_5 is assumed as the position to estimate the ΔL. According to the measure on chart, the distances of A_1A_5, A_2 A_5 and A_3 A_5 are 4.72，3.97 and 3.22 nm.

4.4.2.2 Speed of the incoming vessels

Usually, the speed of incoming vessels is 6-8kn. The estimation is calculated on 6kn, 7kn and 8kn respectively.

4.4.2.3 Average taken time for each TPA per day

If the use ratio of TAP increases, average taken time for each TPA per day decreases. When average taken time by one vessel is short, more vessels can use TAP. The estimation is calculated on 3h, 4h, 5h and 6h respectively.

4.4.2.4 Average vacant time for each TPA per day

Affected by the natural conditions, TAP cannot be used in almost 15% of the days each year. So the average vacant time for each TPA per day is 3.6h, each TAP can be used for 20.4h every day.

4.4.2.5 Average berthing time per day

The berthing time for sixth branch, seventh branch and ninth branch in 2013 is 8069.0h, 8273.3h and 7028.1h, the average berthing time for each day is 22.11h, 22.67h and 19.25h. So average berthing time of all fifteen berths of the three branches is 21.34h.

4.4.3 Saved time and efficiency brought by TAP

Table 4-8 Saved time and efficiency brought by TAP

TAP	Distance (nm)	Speed (kn)	Item	Taken time of TAP(h)			
				3	4	5	6
1#	4.72 (A_1A_5)	6	Saved time (h)	5.35	4.01	3.21	2.67
			Efficiency brought by TAP (%)	1.67	1.25	1.00	0.83
		7	Saved time (h)	4.59	3.44	2.75	2.29
			Efficiency brought by TAP (%)	1.43	1.07	0.86	0.72
		8	Saved time (h)	4.01	3.01	2.41	2.01
			Efficiency brought by TAP (%)	1.25	0.94	0.75	0.63
2#	3.97 (A_2A_5)	6	Saved time (h)	4.50	3.37	2.70	2.25
			Efficiency brought by TAP (%)	1.45	1.41	0.84	0.70
		7	Saved time (h)	3.86	2.89	2.31	1.93
			Efficiency brought by TAP (%)	1.21	0.90	0.72	0.60
		8	Saved time (h)	3.37	2.53	2.02	1.69
			Efficiency brought by TAP (%)	1.05	0.79	0.63	0.53
3#	3.22 (A_3A_5)	6	Saved time (h)	3.65	2.74	2.19	1.82
			Efficiency brought by TAP (%)	1.14	0.86	0.68	0.57
		7	Saved time (h)	3.13	2.35	1.88	1.56
			Efficiency brought by TAP (%)	0.98	0.73	0.59	0.49
		8	Saved time (h)	2.74	2.05	1.64	1.37
			Efficiency brought by TAP (%)	0.86	0.64	0.51	0.43

It is worth noting that TAP saves the vacant time of the berths. If the saved time is not used for handling operation, but wasted on the non-effective berthing period, the transport efficiency cannot be improved.

4.5 Route and navigation method

4.5.1 Navigable waters and route

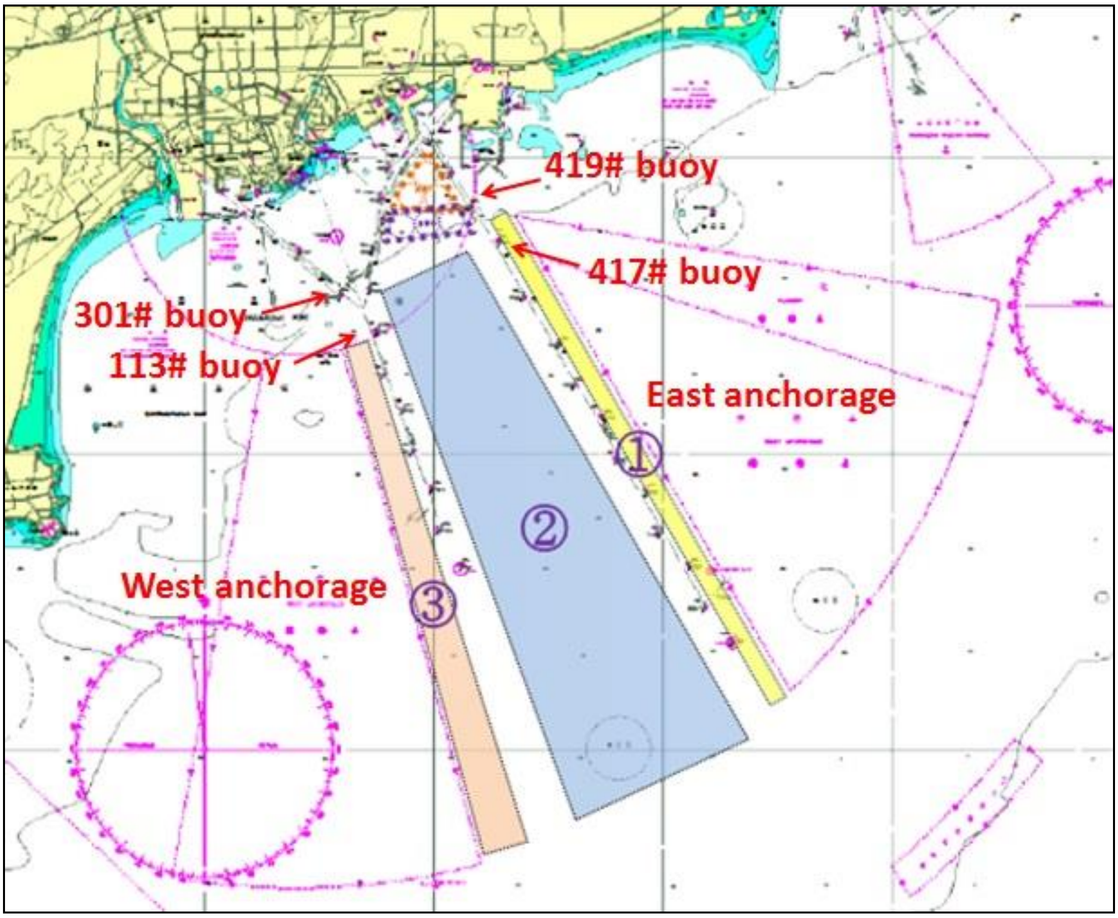


Figure 4-8 Navigable waters and route to enter TAP

Source: Chart 21001, (2011), China MSA.

The vessels from east and west anchorage have three water areas to choose to enter temporary anchor positions (TAP).

Route ① lies in the navigable water between east anchorage and fairway 150. The depth is 10m-17.5m, the navigable water is a rectangular area with the width of 800m. The vessels in east anchorage use this route and cross fairway 150 between 417# buoy and 419# buoy to enter TAP.

Route ② lies in the navigable water between fairway 160 and fairway 150. The depth is 10m-17.8m, the navigable water is a sector area with the width from 2000m to 3800m. The vessels in east and west anchorage can choose to cross fairway 160 and fairway 150, and then use this route to enter TAP.

Route ③ lies in the navigable water between east anchorage and fairway 150. The depth is 10m-17.8m, the navigable water is a sector area with the width from 900m to 1100m. The vessels in west anchorage use this route and cross fairway 160 between 113# buoy and 301# buoy to enter TAP.
(Hebei MSA, 2012)

4.5.2 Impact on traffic flow

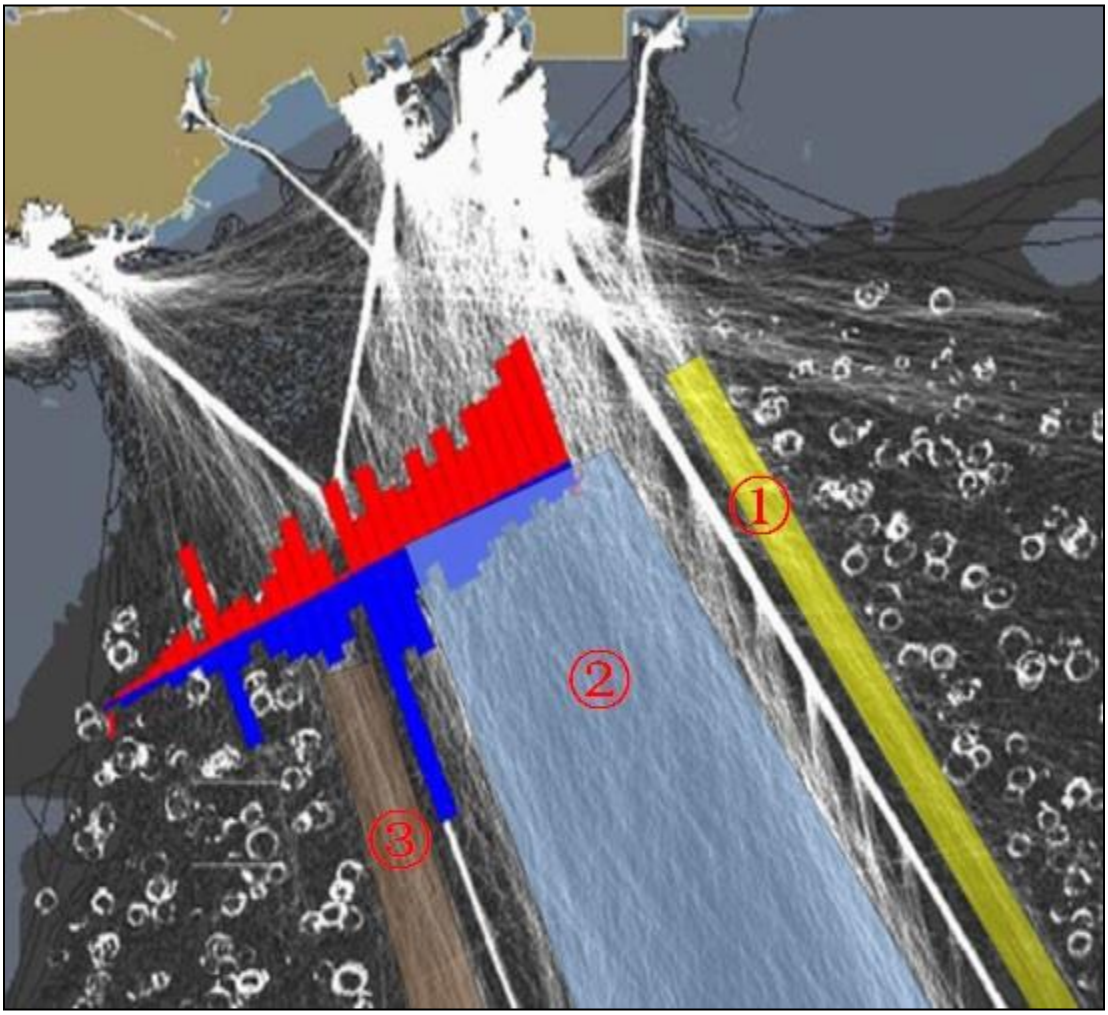


Figure 4-9 Relation between route and traffic flow

Source: Tianjin AIS data center, (2013), Historical data.

From Figure 4-9, the routes are parallel to the direction of the traffic flow. There will be encountered situations between vessels using TAP and in-and-out port vessels. From quantitative perspective, traffic density is much larger in route ②, it focuses in the areas near the fairway 150 and fairway 160.

4.5.3 Comparison and selection of the route

Although route ② has a much larger traffic density, but it applies to vessels in both anchorages and the area is broad. The encountered situations in route ③ and ① will be more dangerous, because it is very close to the fairway and anchorage and the area is narrow, it may increase the risk for vessels in anchorage and fairway.

Due to the complicate traffic situation in route ②, it can be changed to a rectangular area with width of 800m, the direction is 335°. The minimum distance between west boundary and fairway 160 is 2000m, this area is used for the in-and-out port vessels in other harbor area. The minimum distance between east boundary and fairway 150 is 1500m, vessels leaving the port should navigate in fairway 150, vessels entering the port are just the users of TAP.

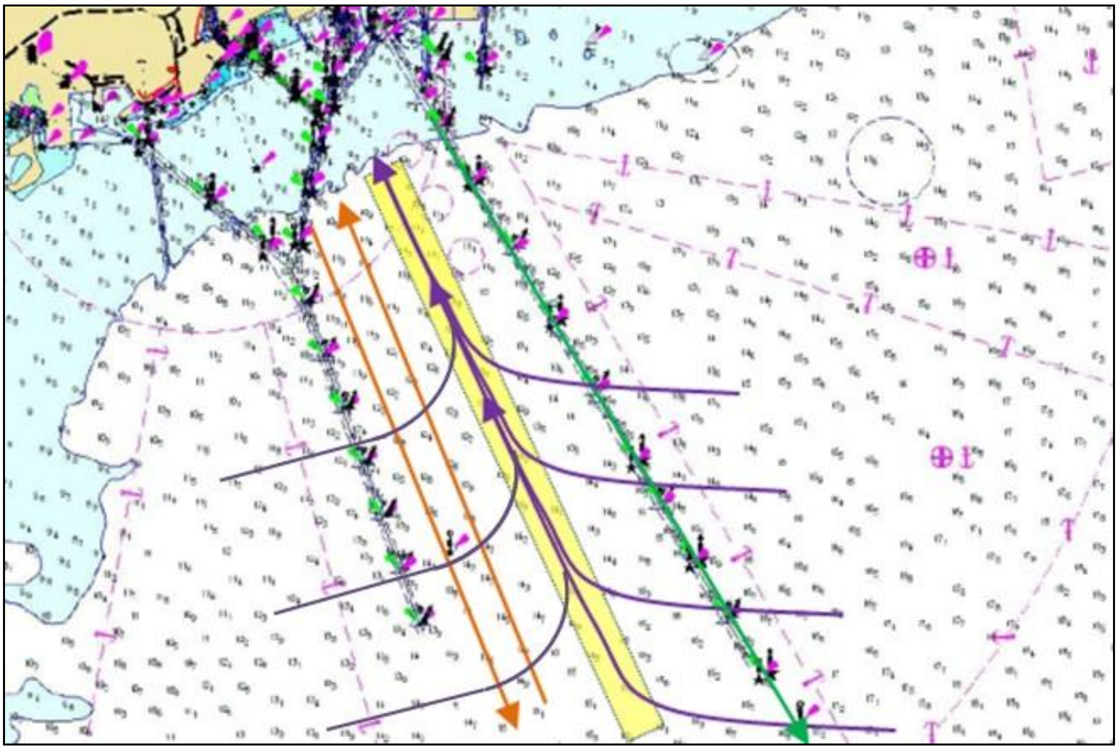


Figure 4-10 Selected route for vessels using TAP

Source: Chart 21115, (2014), China MSA.

Chapter 5 Risk analysis for the temporary anchor positions in the port area

5.1 Introduction to the formal safety assessment

Formal Safety Assessment (FSA) is a structured and systematic methodology, aimed at enhancing maritime safety, including protection of life, health, the marine environment and property, by using risk analysis and cost benefit assessment.(IMO, 2007) FSA comprises the following steps:

1. Preparation for the study: problem definition and generic model.
2. Identification of hazards: a list of all relevant accident scenarios with potential causes and outcomes.
3. Risk assessment: evaluation of risk factors.
4. Risk control options: devise the regulatory measures to control and reduce the identified risks.
5. Cost benefit assessment: determine cost effectiveness of each risk control option.
6. Recommendations for decision-making: define recommendations which should be presented to the relevant decision makers.

FSA bases on data analysis and expert judgment, and it is a combination of both creative and analytical techniques. This section just uses the theory and method of FSA, there has no expert judgment and workshop, also the existing data is not complete enough to finish all steps of FSA, so the risk control options and cost benefit assessment could not be done.

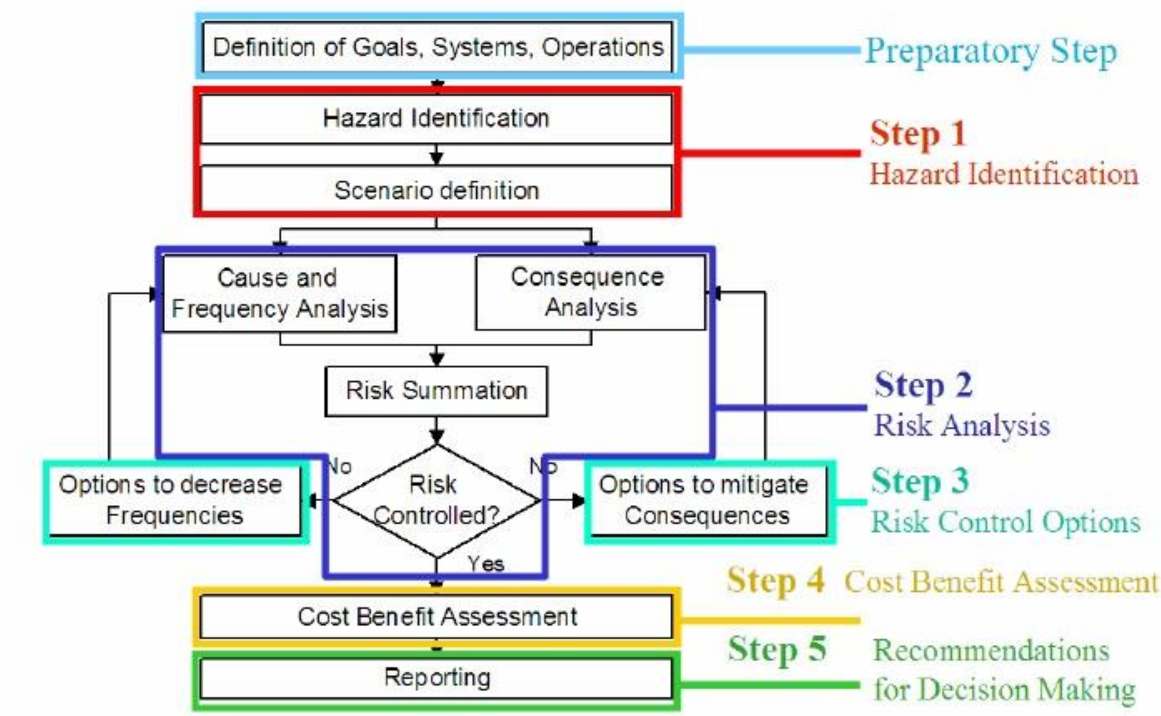


Figure 5-1 Five steps of FSA

Source: IACS FSA training course

FSA is consistent with the current IMO decision-making process and be used as a tool to help in the evaluation of new regulations for maritime safety or in making a comparison between existing and possibly improved regulations.(IMO, 2007) In order to improve the transport efficiency, the temporary anchor positions (TAP) are introduced into the VTS system, TAP is a new management method which will bring some changes to the traffic conditions.

5.2 Preparation for the study

The problem definition is the risk analysis for application of TAP. The content about generic model have been introduced in previous chapters, so they would not be repeated here.

5.3 Hazard identification

5.3.1 Quantitative analysis

As the TAP is located in the port area, meanwhile it is applicable for the coal carriers, the data of accidents does not cover the vessels which pass through the waters of Qinhuangdao port and accidents between fishing vessels or auxiliary operational vessels.

Table 5-1 Accident data 2008-2013

Accident	2008	2009	2010	2011	2012	2013	Sum
Collision	3	6	3	4	1	2	19
Contact	3	0	2	3	4	5	17
Grounding	4	12	2	3	2	1	24
Fire	1	2	0	0	0	0	3
Losing anchor	6	3	4	0	1	1	15
Total accident of the year	17	23	11	10	8	9	78
Total number of ships	15436	14553	14401	14103	12669	11737	82899

Source: Qinhuangdao MSA, (2013).Statistics of accidents.

The fundamental way to calculate accident frequencies is to divide the number of *accidents recorded in a given period by the corresponding exposure for that period.*

$$Incidents\ per\ ship\ year = \frac{Accidents\ reported\ during\ a\ period\ of\ X\ years}{Number\ of\ ship\ years\ acumulated\ during\ X\ years}$$

(IMO, 2008)

Through the formula and data in Table 5-1, the accident frequencies were calculated in Table 5-2.

Table 5-2 Data for accident frequency 2008-2013

	Collision	Contact	Grounding	Fire	Losing anchor	Sum
Accidents from 2008-2013	19	17	24	3	15	78
Ship years 2008-2013	82,899	82,899	82,899	82,899	82,899	82,899
Accident frequency per ship year	2.3E-04	2.1E-04	2.9E-04	3.6E-05	1.8E-04	9.4E-04
Return period No.of ship years per accident	4367	4762	3448	27778	5556	1064

Source: Qinhuangdao MSA, (2013).Historical data of Qinhuangdao VTS.

From historical data, the hazards are represented by five main areas:

1. Collision:
   - Officer on duty not watch-keeping
   - Rough sea conditions (heavy sea and heavy wind)
   - Misoperation of the shipmaster or officer
   - Misoperation of the pilot
2. Contact:
   - Misoperation of the shipmaster or officer
   - Poor visibility

- No chart correction
- Officer on duty not watch-keeping

3. Grounding: - Lose power
- Not familiar with the water area
- Officer on duty not watch-keeping
- Misoperation of the shipmaster or officer

4. Fire: - Electrical faults
- Coal spontaneous combustion

5. Losing anchor: - Officer on duty not watch-keeping
- Rough sea conditions (heavy sea and heavy wind)
- Misoperation of the shipmaster or officer
- Abandon

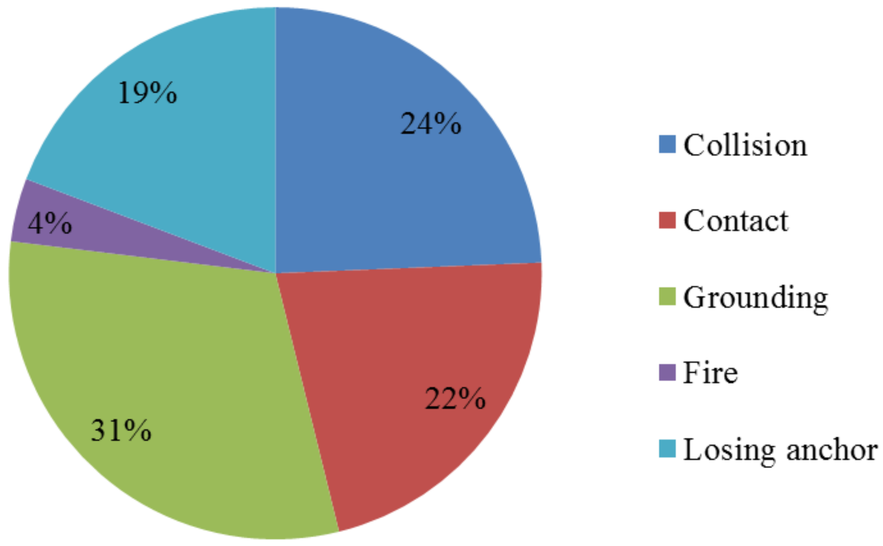


Figure 5-2 Accident distribution

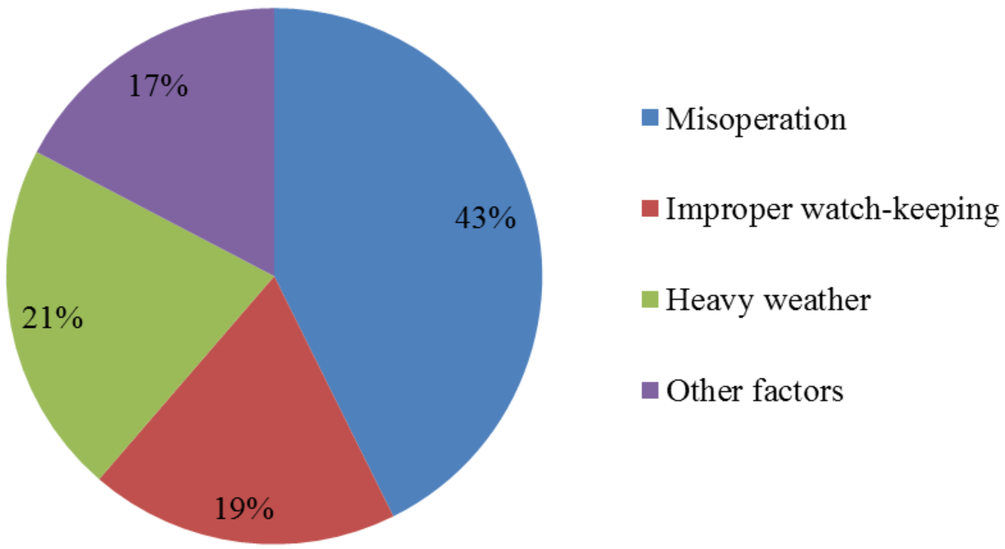


Figure 5-3 Causes of accidents

From data distribution, the main accident types are collision, contact, grounding and losing anchor. The major hazards are misoperation, heavy weather and improper watch-keeping.

5.3.2 Qualitative analysis

This section introduces the hazard identification (HAZID) checklist (DNV, 2005) into the qualitative analysis. From the basic data, we can divide the analysis into two parts: anchoring period (anchor in the TAP) and voyage period (navigate to the TAP). Due to the actual situation of Qinhuangdao port, analysis just focuses on the scenarios with relevant high frequency and serious consequences.

Table 5-3 HAZID checklist

Anchoring period

ID NO	**Hazard** (What can go wrong?)	**Cause** (Why can it go wrong?)	**Consequences** (What does it lead to?)	**Preventive safeguards** (How can it be prevented?)	**Mitigating safeguards** (How can it be mitigated?)
1.1	Strong wind or heavy waves	-	-Dragging of anchor -Contact with buoy or pier -Collision with other ships -Grounding -Hull damage, flooding and oil pollution	-Monitoring the weather and tide conditions -Monitor traffic -Strengthen watch-keeping	-Drop the other anchor -Tug assistance -Immediate engine start-up -Engines on standby mode -Report to the port authority immediately
1.2	Force of the ice	-			
1.3	Officer not watch-keeping	-Physical or psychological problems -Incompetence		-Supervision from senior officers -Improvement of the management system	
1.4	Anchor chain breaks	-Bad maintenance	-Lose anchor or chain -Contact with buoy or pier -Collision with other ships -Grounding -Hull damage, flooding and oil pollution	-Improvement of the management system -Regular maintenance	
1.5	Wrong anchor position	-Unreliable electronic charts	-Collision with other vessels	-Supervision from senior officers	-Correct the anchor position

		-Incompetent seafarers -Physical or psychological problems of the seafarers		-Improvement of the management system -Regular maintenance	
1.4	Anchor equipment failure	-Bad maintenance	-Personnel injury -Unable to release anchor	- Regular maintenance	-Treat victims -Report to the port authority immediately -Repair(just for 1.4)
1.5	Incorrect operation of anchoring	-Incompetent seafarers -Physical or psychological problems of the seafarers	-Personnel injury	- Training and awareness - Personal Protective Equipment -Improvement of the management system	
Voyage period					
ID NO	**Hazard** (What can go wrong?)	**Cause** (Why can it go wrong?)	**Consequences** (What does it lead to?)	**Preventive safeguards** (How can it be prevented?)	**Mitigating safeguards** (How can it be mitigated?)
2.1	Heavy traffic density	-	-Collision with other ships -Contact with buoy or beacon	-Strengthen watch-keeping -Keep the safety speed	-Physical barriers (bulkheads) -Ship design (damage stability) -Report to the port authority immediately
2.2	Poor visibility	-			
2.3	Strong wind or heavy waves	-		-Anchoring -Tug assistant	
2.4	Force of the ice	-			

<table>
<tr><td>2.5</td><td>Steering gear / rudder failure</td><td rowspan="3">-Bad maintenance
-Random failure</td><td rowspan="4">-Collision with other ships
-Contact with buoy or beacon</td><td rowspan="3">-Test maneuverability prior to departure
-Training on vessel maneuverability</td><td rowspan="6">-Physical barriers (bulkheads)
-Ship design (damage stability)
-Report to the port authority immediately
-Repair(just for 2.5-2.7)</td></tr>
<tr><td>2.6</td><td>Loss of maneuver and power control (equipment failure)</td></tr>
<tr><td>2.7</td><td>Unreliable navigational aids</td></tr>
<tr><td>2.8</td><td>Officer not watch-keeping</td><td>-Physical or psychological problems
-Incompetence</td><td>-Supervision from senior officers
-Improvement of the management system</td></tr>
<tr><td>2.9</td><td>Pilot incompetence</td><td>-</td><td rowspan="2">-Collision with other ships</td><td>-</td></tr>
<tr><td>2.10</td><td>Bad pilot interface with master</td><td>-Language barriers
-Discrimination</td><td>-Establish good communication between pilot and master</td></tr>
<tr><td>2.11</td><td>Badly rigged transfer arrangements</td><td>-Incompetent seafarers
-Insufficient communication between pilot and master</td><td>-Personnel(crew/pilot) injury</td><td>-Regular inspections of boarding arrangements(incl.ladders)
-Pilot safety training
-Good communication between pilot boat and ship</td><td>-Treat victims
-Report to the port authority immediately</td></tr>
</table>

Through the HAZID checklist, some of the hazards were merged into other hazards as they were quite similar. Then, the hazards are rated by the group in order of importance: collision hazards and personal injury hazards.

Five major hazards with regard to collision, grounding and contact identified:

1. Severe weather
2. Officer on duty not watch-keeping
3. Failure of critical navigational aids
4. Severe loss of functionality (e.g. loss of rudder/steering)
5. Misinterpretation of bridge information

Two major personal injury hazards identified:

1. Incorrect operation of anchoring
2. Anchor equipment failure

5.3.3 Screening of risks

To facilitate the ranking and validation, it is generally recommended to define consequence and probability indices on a logarithmic scale. A risk index may therefore be established by adding the probability/frequency and consequence indices.

$$Risk = Probability \times Consequence$$

$$Log\ (Risk) = log\ (Probability) + log\ (Consequence)$$

(IMO, 2007)

According to the historical data from Table 5-2 (Data for accident frequency from 2008-2013) and actual situation of Qinhuangdao port, the frequency index and severity index (Schröder, 2013) are assumed as follows:

Table 5-4 Frequency index (FI) for risk analysis of TAP

FI	Frequency	Definition	Value (per ship year)
F4	Frequent	Likely to happen once per month on one ship	1E-03
F3	Reasonably probable	Likely to happen once per year on one ship	1E-04
F2	Remote	Likely to happen once per year in a fleet of 10 ships	1E-05
F1	Extremely remote	Likely to happen once per year in a fleet of 100 ships	1E-06

Table 5-5 Severity index (SI) for risk analysis of TAP

SI	Severity	Effect on human safety	Effects on ships	S (Equivalent fatalities)
S1	Minor	No casualties	Local equipment damage	0.1
S2	Significant	Single to three minor injuries	Non-severe ship damage	1
S3	Serious	Single severe injury Three or more minor injuries	Severe damage	10
S4	Very serious	Single fatality Three or more serious injuries	Total loss	100

Based on the two tables above, the risk index can be found out.

Table 5-6 Risk index (RI) for risk analysis of TAP

Risk index					
FI	Frequency	Severity(SI)			
		S1	S2	S3	S4
		Minor	Significant	Serious	Very serious
F4	Frequent	R5(F4 S1)	R6(F4 S2)	R7(F4 S3)	R8(F4 S4)
F3	Reasonably probable	R4(F3 S1)	R5(F3 S2)	R6(F3 S3)	R7(F3 S4)
F2	Remote	R3(F2 S1)	R4(F2 S2)	R5(F2 S3)	R6(F2 S4)
F1	Extremely remote	R2(F1 S1)	R3(F1 S2)	R4(F1 S3)	R5(F1 S4)

According to the qualitative analysis, the judgments on hazard rating are as follows:

1. Severe loss of functionality: R7 (F4 S3)
2. Officer on duty not watch-keeping: R6 (F4 S2)
3. Failure of critical navigational aids: R5 (F2 S3)
   Severe weather: R5 (F3 S2)
   Anchor equipment failure: R5 (F3 S2)
4. Misinterpretation of bridge information: R4 (F2 S2)
   Incorrect operation of anchoring: R4 (F3 S1)

5.4 Risk assessment

5.4.1 Introduction

The construction and quantification of fault trees and event trees are standard risk assessment techniques that can be used to build a risk model.(IMO, 2007)

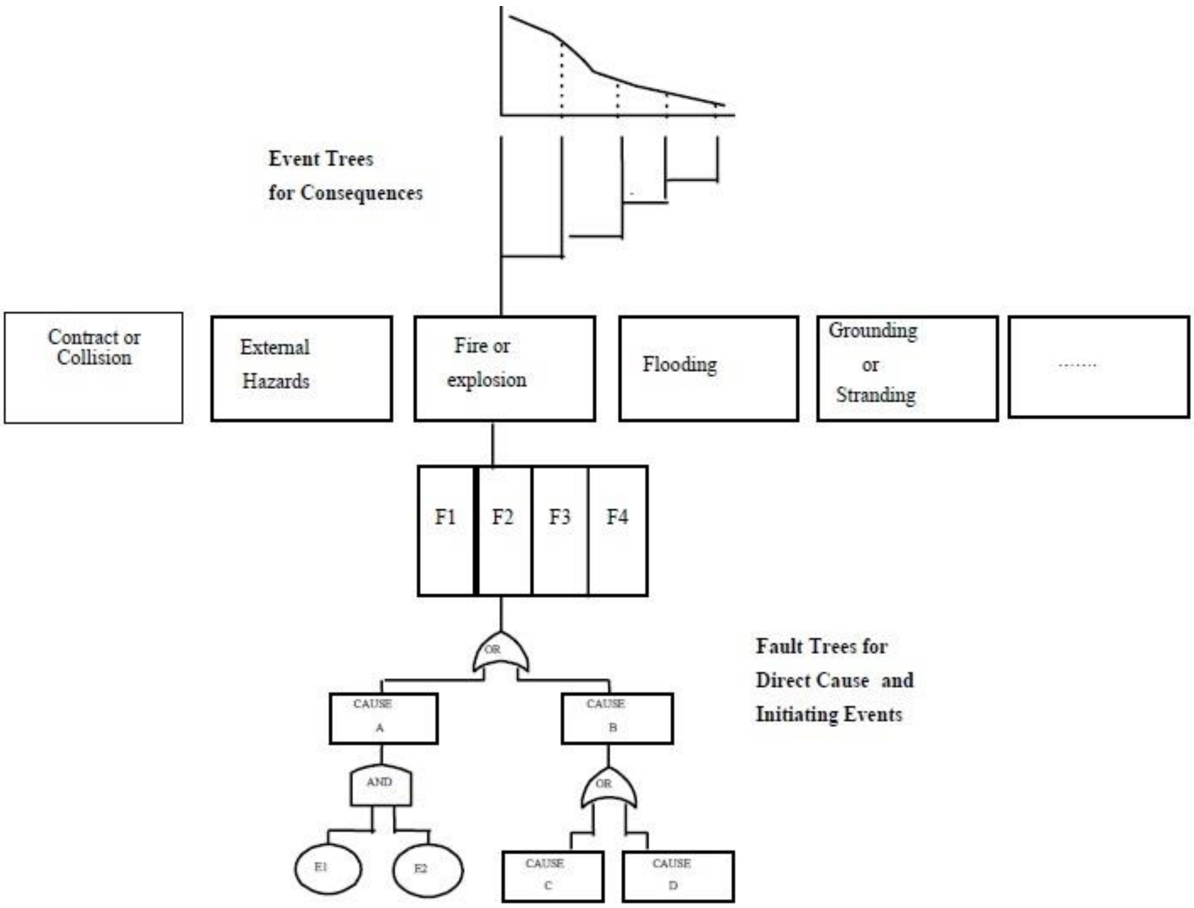


Figure 5-4 Risk contribution tree (connection between fault and event trees)

Source: Consolidated text of the Guidelines for Formal Safety Assessment (FSA) for use in the IMO rule-making process

A fault tree provides a structured system to model the final (top event) accident frequency from a set of initiating faults. In this study, the fault trees models have not been used to determine the accident frequencies, the accident frequency has been calculated from the historical data.

The event tree applies to the analysis for the consequences. An event tree starts with an initiating event. A probability of occurrence of the particular outcome is estimated for each branch, the outcome probabilities are determined by the input frequencies from historical data plus the various probabilities along the branches leading to the outcome. The probabilities along the branches are assumed from the judgment of actual situation.

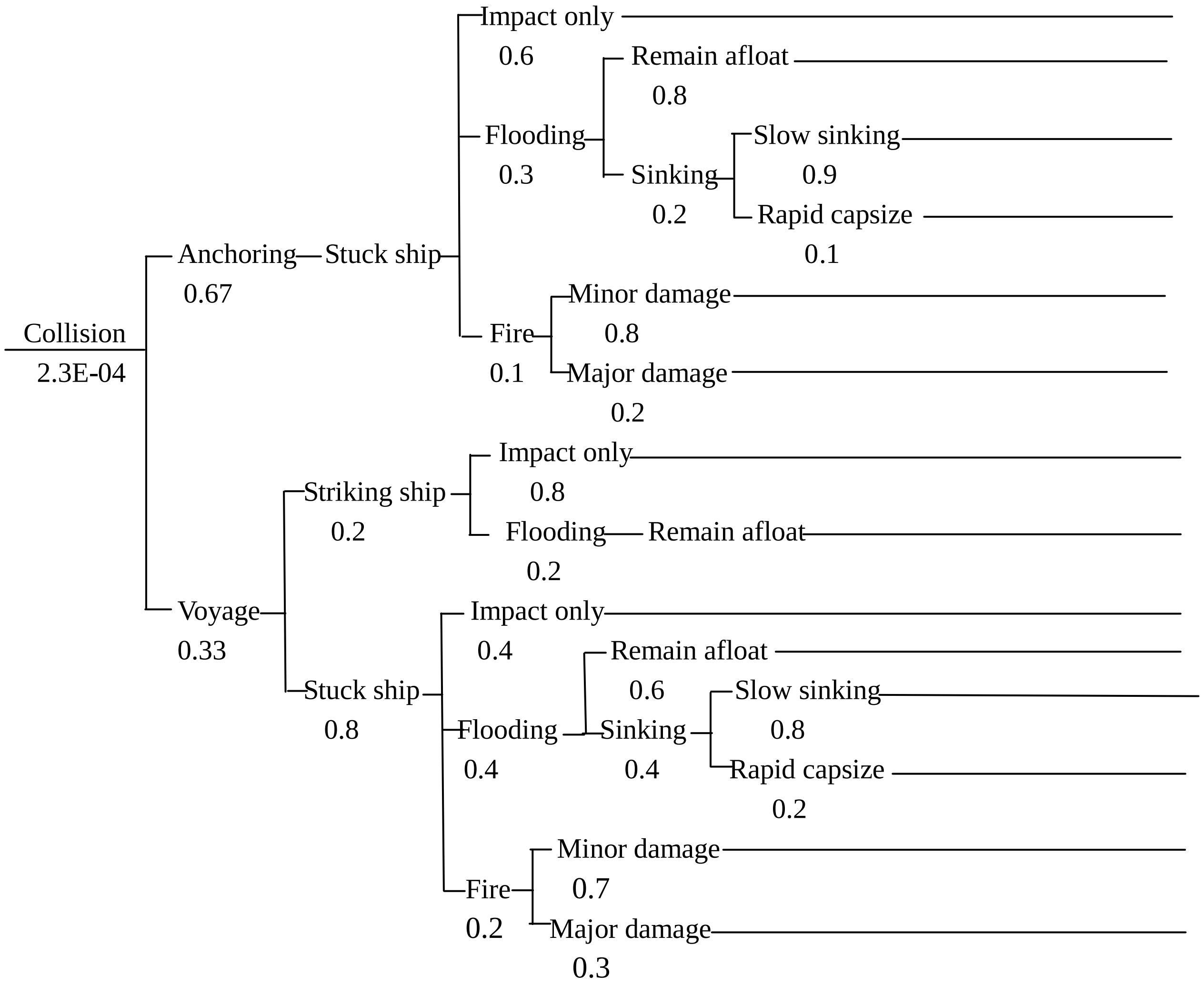
According to the actual situation of the Qinhuangdao port, the crewmember of the vessels involved in the risk analysis of TAP are less than 20. So the number of people on board for all the vessels is assumed as 20.

5.4.2 Event tree

From historical data (Table 5-2 accident frequency), the main accidents are collision, contact, grounding and losing anchor.

As for the features of the port waters, the depth meets the draught of the vessels using the TAP, also there are no obstructions and shallow waters through the route to the TAP, so it is impossible for the vessels to get grounding in voyage period. Meanwhile TAP is quite far away from the shallow waters in the dock area, the grounding in anchoring period and contact are highly unlikely to happen (most of contact from historical data happen in berthing and unberthing operation, groundings happen in departure of the port). Losing anchor is minor accident, it does not cause fatalities. So the event trees analysis just focuses on collision, input frequency for collision is 2.3E-04. Event tree for collision has been developed and illustrated in Figure 5-5.

Figure 5-5 Collision event tree (Expected fatalities: EF, Per ship year: psy)



EF per accident	Collision psy	Fatalities psy
0	9.2E-05	0
0	3.7E-05	0
2	8.3E-06	1.7E-05
16	9.2E-07	1.5E-05
2	1.2E-05	2.4E-05
5	3.1E-06	1.6E-05
0	1.2E-05	0
0	3.0E-05	0
0	2.4E-05	0
0	1.5E-05	0
2	7.8E-06	1.6E-05
14	1.9E-06	2.7E-05
2	8.5E-06	1.7E-05
5	3.6E-06	1.8E-05

For level 1, the time for vessels waiting in the TAP has been stipulated in the previous chapter, it is less than 6 hours. The voyage period from anchorage to the TAP is less than 2 hours. So the probability for anchoring period is two times of the voyage period.

For level 2, when vessel anchors in the TAP, the collision is caused by vessels navigating in the port waters, the minor damage for the striking vessels can be neglected. A typical collision between ships involves one ship striking another in the side with the bow first, as the bow is a fairly well protected area, the struck ship will typically sustain greater damage as the sides of the ship are structurally weaker, so the probability is much higher for the stoke vessels.

For level 3, level 4 and level 5, the speed of the traffic flow in the port waters is relatively slow, the probability of flooding is low, so the incidence of major accident is low. When vessel anchors in the TAP, it is steady, the impact force in collisions is much lower than the ones in voyage period, so the probability is different.

5.4.3 Risk criteria

Table 5-7 Risk acceptance criteria

Decision parameter		Acceptance Criteria	
		Lower bound for ALARP region	Upper bound for ALARP region
		Negligence (broadly acceptable) fatality risk per year	Maximum tolerable fatality risk per year
Individual Risk	To crew member	10^{-6}	10^{-3}
	To passenger	10^{-6}	10^{-4}
	To third parties, member of public ashore	10^{-6}	10^{-4}

	Target values for new ships	10^{-6}	Above values to be reduced by one order of magnitude
Societal Risk	To groups of above persons	To be derived by using economic parameters as per MSC 72/16	

Source: Consolidated text of the Guidelines for Formal Safety Assessment (FSA) for use in the IMO rule-making process

From Figure 5-5, the fatalities per ship year in collision is 1.5×10^{-4}, and the crewmember on board is assumed as 20, so the individual risk for crew is 10^{-5} fatalities per year. In HSE (Health Safety Environment System), the individual risk criteria is 10^{-6} to 10^{-3} fatalities per year, the individual risk level for crew is in the ALARP area, it means that according to the IMO guidelines the risk for crew and passengers should be reduced as long as the risk reduction is not disproportionate to the costs. i.e., (IMO, 2008) only cost beneficial RCOs need to be implemented

Societal Risk is used to estimate risks of accidents affecting many persons, e.g. catastrophes. (IMO, 2007), the analysis above has shown that the application of TAP will not generate accidents that affect many persons, so the societal risk analysis is left out.

5.5 Recommendations

Through the risk analysis, the application of TAP is practicable from safety standpoint. Although the accident frequency is low, there are still some possibility for the serious consequence to happen. In order to ensure the safety of vessels, the authority needs to take proactive measures conducted by traffic management from macroscopic point of view.

1. Promulgation of the TAP regulation

The port authority and MSA should formulate the regulation for TAP which stipulates the operating conditions and procedures, also there should be some provisions for punishment to the violations. Meanwhile the regulation should be informed to the fishery administration and other interested parties in the port. The regulation should have constraints to ensure fishing boats not to affect the vessels anchoring in the TAP.

2. The role of VTS for organization and coordination

Because of the integrative view for the traffic environment, VTS has almost all the dynamic informations in the port. In the trial operation, VTS should remind the vessels which navigate in the port waters to keep clear from the vessels anchoring in the TAP, give effective guidance to the traffic flow. According to the weather condition, VTS should control the operating conditions of TAP, ensure the TAP to be shut down in the heavy waves, gale and floating ice. Arrange the vessels to enter the TAP in good order, avoid accidents between vessels using the TAP, this may need a period of time to accumulate experiences for operation.(China MSA, 2011)

3. Training for TAP

The shipping companies are responsible for the training, the objects of the training are senior officers who have a direct connection with the application of TAP. Not only the operating conditions and procedures, but also the safety awareness should be the emphasis of the training. (Baumler, 2014) The senior officers should be told to realize that anchoring in the TAP is not like in the anchorage, the traffic density around TAP is very heavy, and they should be more careful than voyage period.

4. Screening the vessels

In the trial operation, port authority should select vessels with better condition and management, MSA examines the inspection record of the selected vessels. These are used to ensure that the vessels using TAP are in good condition, there would not have problems like loss of functionality and equipment failures. (Duan, 2006)

Chapter 6 Conclusion

This research attempts to explore the feasibility of temporary anchor positions (TAP). Through the analysis and calculation of the historical data, the key points to improve the transport efficiency for coal carriers in Qinhuangdao port are found out. Based on the improvement of efficiency and actual situation of the port, the plan of TAP is selected.

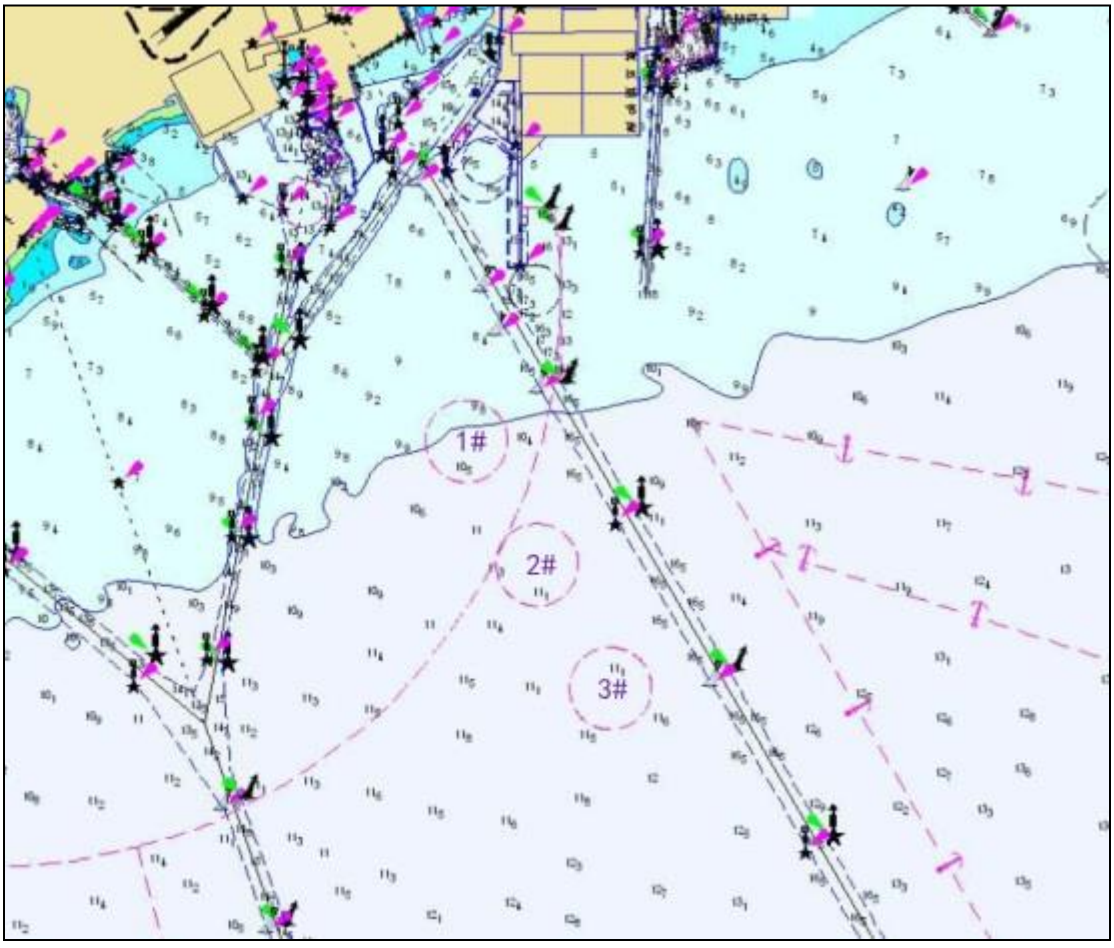


Figure 6-1 Layout plan of TAP

Source: Chart 21115, (2014), China MSA.

The radius of the anchor position is 400m, the distance between centers of circles is 1400m. The line that connects the centers is parallel to fairway 150, it is 900m away from the west boundary of the fairway 150. The coordinates are as follows:

1# anchor position: 39°53′53″N 119°40′13″E
2# anchor position: 39°53′14″N 119°40′42″E
3# anchor position: 39°52′35″N 119°41′12″E

Through calculation, the saved time and improved efficiency brought by TAP are found out in Table 4-8. For example, when vessels use 1# anchor position, if each vessel waits 3 hours and speed is 7kn, the saved time and improved efficiency is 4.59h and 1.43% in one day for 1# anchor position alone.

In order to verify the safety of the TAP, Formal Safety Assessment (FSA) is introduced to analyze the risk. The result meets the requirements of the risk acceptance criteria.

Theoretically TAP is feasible and effective, its effect and safety still need to be validated by implementation which are assumed to be complicated. The cooperation among MSA, port authority, shipping company, crew members and other departments are important. Regulation for TAP should be formulated to ensure the smooth running. VTS plays an even more important role in organization and coordination for port traffic system, crewmembers should be trained to focus on safety. Only by these ways could the TAP safely serve the port properly, thereby improve the transport safety and efficiency in the long run.

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