Delft University of Technology

"A feasibility study for a deep-water port in Haiphong, Vietnam"

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Preface

This report is the master thesis of Tjitske Wiersma, student of Delft University of Technology, Faculty of Civil Engineering and Geosciences. The thesis is the last project of the study Civil Engineering. My specialisation is Hydraulic Engineering, in what I chose my final subjects in the Port & Inland Waterways specialisation.
The subject of this report is the feasibility of a deep-water seaport in the Haiphong area (Vietnam). This project has been carried out under guidance of the graduation committee. I would like to thank the members of my graduation committee for their comments and support during my project. The members of this committee are:

Prof. Ir. H. Ligteringen (DUT)
Ir. R. Groenveld (DUT)
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Furthermore I would like to thank the Vietnam Maritime University and especially Mr. Son for their great hospitality and help during my stay in Vietnam. I would like to thank Mr. De Bruin and Mr. Bakker as well, for their advice and useful reports. Finally I would like to thank my family and friends for their support during the years I spent in Delft and especially the months I spent on my thesis.

Tjitske Wiersma
Delft, December 2003

Figure: existing port of Haiphong

Summary

In Vietnam both international and domestic trade have grown tremendously in the last fifteen years. Therefore the throughput in Vietnamese ports is increasing rapidly. The capacity of the existing Haiphong port is not sufficient. At the moment the port is already operating above its maximum design capacity. Congestion is one of the main problems and expansion is not sensible due to the limited water depth of the river. Also the maintenance costs are very high because of the huge amount of siltation in the navigation channel. The foresight is that the port will not be able to handle the expected container throughput anymore in the very near future.

A comprehensive feasibility study for a deep-water port in the surroundings of Haiphong was not yet available. Therefore this study includes the proposed development and its viability from a technical point of view. Two locations have been looked at, i.e. Cat Hai and southwards of Doson peninsula. Other possible locations were eliminated beforehand.

The expected throughput for the deep-water port of Haiphong in the year 2020 is 25 mln tons of cargo. Initially it was desirable to design a port that was able to handle vessels with a capacity of 80.000 DWT. Considering the expected throughput for the complete Haiphong area in 2020 (33.5 mln tons) and the cargo flow that is ensured from that expectation, it does not seem realistic to expect the 80.000 DWT vessels in the new deep-water port. Therefore the port in this study is designed to handle container vessels of 54.000 DWT (4.500 TEU) and 30.000 DWT general cargo vessels.

For both locations two sub-variants have been designed considering the requirements for the water layout. A Multi Criteria Evaluation (MCE) was carried out to determine the most suitable (sub-) variant. In this evaluation the qualitative properties have been deliberated separately from the costs. Afterwards the value/ cost ratio has been determined. The location south of Doson appeared to be the most suitable, both in the cost and in the value ranking of the MCE, mainly because of the more favourable hinterland connections. With the help of the queuing theory the necessary quay length has been determined for each type of vessel. Four container berths, three general cargo berths and two inland barge berths are necessary to handle all incoming vessels without too much waiting time.

A list of requirements has been drawn up as a result of different calculations on channel width, length, terminal dimensions, berths, natural conditions etc.
Four sub-variants for the port layout have been developed for the location south of Doson peninsula. These sub-variants differ in landfill/ dredging ratio, port basin and positioning of the access channel. The terminal layout has not been developed in this stage of the study; the land surface for each sub-variant is sufficient to accommodate all necessary terminal facilities.

Another MCE has been carried out. From this evaluation appeared that sub-variant 1, a rather narrow pier that stretches out to the deeper part of the sea, is the most suitable when the ranking of the best value and value/ cost ratio are concerned. This sub-variant is more expensive than no. 3, but it is much safer and it answers more of the demands and desires in advance posed. Therefore sub-variant 1 has been worked out in further detail.

The access channel is one of the main components of a port. Because of the large amounts of dredging, high costs are involved. Therefore the access channel has been optimized without exceeding the acceptable waiting times for the different vessels. This optimizing has been done by means of a computerized simulation program, called Harborsim. The access channel has been modelled to a system of different sections in which the vessels sail from sea to quay and back. Permission for this trip is only given when all sections fulfil certain traffic rules. No unwanted meetings of the different vessels are allowed. A tidal window plays part in this process as well.
Given the tidal and wave data that were available during this study, the most optimal design for the access channel is a one-way channel in which a tidal window of +1.40 m CD will be in effect. The accompanying lengths are 1401 m for container quay and 678 m for the general cargo quay.
However, extensive data collection on morphology, tides, currents, waves and winds should be carried out and taken into account before this can be concluded.

A preliminary map for the terminal layout has been designed. The main components for both terminals (container and general cargo) are grouped and the terminal infrastructure has been determined.

The existing hinterland connections (both inland waterways, road- and railway network) are not sufficient. Not only the connection to Haiphong should be constructed, but larger improvements on the tracks to the further hinterland are necessary as well.

The costs for this project have been estimated at $405 mln. This only includes the construction costs of the components. Maintenance costs, costs for machinery, water- and power supplies, navigational aids, harbor equipment and transportation at the terminal have not been taken into account. Large items are the railway connection, the Container Freight Station, container quays, dredging and landfill.

Many risks are involved in carrying out this project. The largest risk for the feasibility of this project is the uncertainty as far as the throughput expectation is concerned. This factor is not only influenced by Vietnam and its economy, but also by the world economy. A remedy will be to construct the project in phases and to keep enough space to extend the port when necessary. In that way fluctuations in the cargo throughput can be caught.

Finally it can be concluded that it is necessary and technical feasible to build this new deep-water port. The economic feasibility should still be proven by carrying out a thorough cost-benefit analysis.

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1 Introduction

1.1 Reason for this study

"From late 1980s, the Vietnamese government committed itself to the "Doi Moi" policy, or renovation. The core of this policy was liberalization and deregulation of the economy, with a strategic shift towards private sector development and agricultural reform. The Government made export-led growth a primary goal. The attraction of foreign investment became an integral part of this objective." [5]

One of the consequences of this “Doi Moi” policy is that both international and domestic trade have grown tremendously in the last fifteen years. This did not happen unnoticed; for example the throughput of Haiphong port, the main port of Vietnam, is increasing rapidly. At the moment the port is operating far above the capacity where it was originally designed for.

There are many reasons why the authorities of Haiphong and the Vietnamese government would like to develop a new (deep-water) seaport in Haiphong. Two of them are the following. The worldwide containerisation and the percentage of Panamax size fleet are growing. The ships that want to visit Haiphong become larger and larger because of this. The depth of the access channel is insufficient at the moment. The second reason is that Vietnam wants to join the competition between the other Asian countries in the region that all have a deep-water port. In Vietnam no deep-water port has yet been constructed. Hence this study will investigate the feasibility of a new deep-water port in Haiphong.

1.2 Description project area

Haiphong is situated on the north-eastern coast of Vietnam, about 100 km east of Hanoi. It is the third largest city in Vietnam and possesses the largest seaport in the northern part of the country. It covers an area of 1.519 square km, including two island districts (Cat Hai and Bach Long Vi). Haiphong is located in the Red River Delta, with an average elevation of +0.7 m to +1.7 m above sea level.

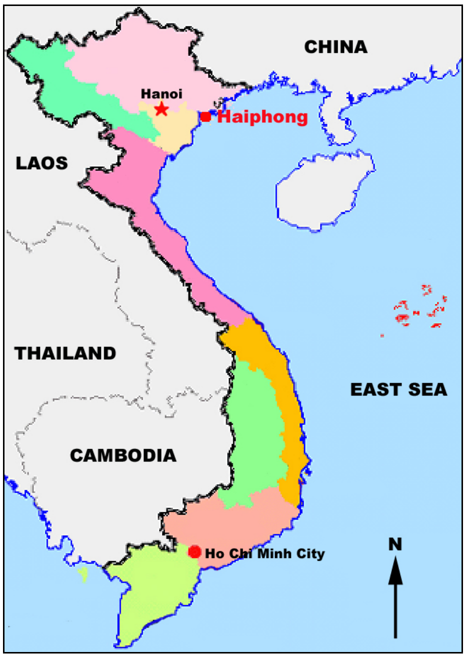

Figure 1.1: map of Vietnam

Haiphong has a large coastal and sea area, favourable for marine economic development. The city is located in the tropical climate zone with an annual average temperature of 24˚ Celsius, annual rainfall of 1600-1800 mm and average humidity of 85%.

Haiphong is the most important commercial and transportation hub in northern Vietnam, connecting the Northern provinces with the world market through its seaport system. Other parts of the country are connected to Haiphong by road, railway, inland waterways, sea and air links.

Figure 1.2: map of the area

1.3 Problem analysis

In the next subsection the problems in the existing Haiphong port will be described. On the basis of this description the problem, which will be dealt with in this study, is defined in the second subsection.

1.3.1 Problems in Haiphong port

One of the problems is congestion in the existing port of Haiphong. Expansion is not sensible due to the limited depth. This immediately provokes the second problem of the existing port, namely the very high maintenance costs, which are so, because of the huge amount of siltation in the navigation channel. The dredging capacity of the existing fleet is far less than the magnitude of the current siltation rate. The channel depth has been shallowing year-by-year forcing to downsize the ships calling in Haiphong Port, eventually leading to decrease in shipment size at Haiphong Port.

Nowadays the existing port can accommodate ships of 10.000 DWT at most. In future it would be desirable to accommodate ships up till 80.000 DWT. Several other ports are under construction, but will not be able to cater for large enough ships.
Therefore a feasibility study for a deep-water port in the Haiphong area is needed; it is not yet available however. The most favourable location for this port has not been determined yet.

1.3.2 Problem definition

A comprehensive feasibility study is required but not yet available. This study should include the proposed development and its viability, from a technical and economic point of view. This study will be written for the Vietnam Maritime University (Vimaru), the Vietnamese Government and Delft University of Technology.

1.3.3 Objective

The main objective formulated for this study is:
Determine the feasibility of a deep-water port in the Haiphong area.

During the study it has been tried to answer the following questions.

- Is the project viable?
- What are the most important risks?
- What will be the basic layout of the project?

- What will be the basic plan for realisation and exploitation?

This has been done from a technical point of view. Time was too short to answer above questions from an economical point of view as well.

1.4 Assumptions/ limitations before start

At the start there were just a few points known and only a couple of assumptions were made. Extensive data collection will help to shorten the list of assumptions, enlarge the enumeration of starting points and to set up a list of requirements.

At the start of this study the following points were known:

- Location of the port: two variants, first one is south of Doson peninsula and the second is in the extended Dinh Vu area (in between the mouths of the rivers Nam Trieu and Lach Huyen)
- The estimated investment (up to the year 2020) is 1 billion USD
- The design vessels are 80.000 DWT and 6.000 TEU
- The main kinds of cargo are multipurpose cargo and containers
- The existing port has a water depth of -5.7 m CD (ships of 10.000 DWT)

1.5 Report structure

Chapter 2 covers the results of the data collection, which was carried out in Vietnam. On the basis of these data, calculations on terminal dimensions have been performed, and rough layouts for both locations have been designed in chapter 3. A Multi Criteria Evaluation has been carried out as well, to determine the most favourable location for the port. Chapter 4 consists of the determination of 4 sub-variants, which differ in the morphology, access channel, port basin, landfill/dredging ratio and economic aspects. These sub-variants have been evaluated in chapter 5. The design of the access channel has been optimised by means of the simulation program Harborsim. The results of this simulation can be found in chapter 6. Thereafter follows the terminal layout and cost estimation in chapter 7. Furthermore an executive planning gives insight in the estimated construction time of the project. Finally the conclusions and recommendations have been spread out in chapter 8.

2 Data collection

2.1 Introduction

This chapter will cover the results of the data collection. Part of this study has been done in the Netherlands where a literature study was carried out. The other part of the study was carried out in Vietnam. The existing port of Haiphong, the Dinh Vu Economic Zone, as well as the surroundings of Haiphong, were visited and authorities of different organisations were questioned.
At the end of this chapter a list of demands for the design of the Haiphong deep-water port is formulated.

2.2 Geography

This section describes some geographic conditions of Haiphong and its neighbouring ports.

2.2.1 Location

Haiphong City is located in northern Vietnam, in the Red River Delta. The city has a population of 1.744.970 (2002).
The port of Haiphong is situated along the Cam River. Through a small canal this river is connected with the Nam Trieu River, which flows into the Gulf of Tonkin.

For the new deep-water port two locations will be looked at, which both are shown in figure 2.1. More detailed maps can be found in Appendices VII and IX. The first location is the extended Dinh Vu area. Dinh Vu exists of two peninsulas. The one that is situated westwards of the River Nam Trieu is being developed as a new industrial zone at the moment. The other one is located at the eastside of the River Nam Trieu (no. 1 on the map). The surroundings of this peninsula are shallow; there is a possibility to extend the land and build a new deep-water port south of the Trap Canal near the mouth of the Nam Trieu River. The coastal area of this peninsula is called Cat Hai. From now on this location will be referred to as the “Cat Hai” location.

Figure 2.1: map of two possible locations

1 Cat Hai location
2 Southwards of Doson peninsula

The other option is to build the port southwards of Haiphong at the Doson peninsula (no. 2 on the map). At the northern part of the peninsula three public beaches are situated. The area south of the peninsula is also shallow, but rather close to the deeper parts of the Gulf of Tonkin. Just south of this location the River Van Uc flows into the Gulf of Tonkin. It has to be said explicitly that the peninsula itself is no option as possible location, because of its present function. In this study specifically the area south of Doson is involves.

Figure 2.2: both locations, Cat Hai (left), and southwards of Doson (right)

2.2.2 Neighbouring ports

Quite a few ports are located in the Haiphong area. The deep-water port will be situated near the coast; this will keep the high dredging costs as low as possible. The surrounding ports will partly handle cargo from a competing point of view, partly in another market field. In the future the ports will need to work together and combine their strong points in order to create an even more effective port structure.
In this section the neighbouring ports will be shortly addressed. The location of the ports can be found in figure 2.3 on the next page.
The existing port of Haiphong is located on the Cam River, 30 km upstream of buoy no. 0 of the access channel. This port can handle vessels with a maximum of 10.000 DWT. It handles general cargo, RoRo, dry bulk and some containers. Twelve berths are available, the total quay length is 1700 m and the depth at the berths is 8 m. The total capacity of the Haiphong port, after implementation and upgrading in the last couple of years, was expected to be 8.5 mln tons per year. Last year though, they exceeded this amount and handled 10.4 mln tons. Further extension is neither possible nor desirable at this location; the port authority only wants to extend the port in ocean direction.
Part of the Haiphong port is the **Chua Ve terminal**, located about 4 km downstream of the main port. Unlike the main port, Chua Ve port serves container shipment only. The port has a 480 m long quay wall, consisting of three berths, two of them old and one which was built in 2001. This year the construction of another two berths will be started, which is expected to be finished and operating at the end of 2005. Like the Haiphong main port, this terminal can accommodate vessels with a maximum of 10.000 DWT.
Dinh Vu port is still under construction. This port will be situated on the Dinh Vu peninsula, 6 km southwest of Haiphong port. This peninsula has a length of approximately 7 km and is laying in between the rivers Bach Dang and Cam. Planned is to accommodate ships with a maximum of 10.000 DWT initially and up to 30.000 DWT in later development stages. The first quay of 425 m (to accommodate two ships) is expected to be finished at the end of 2004. Haiphong port will be the owner of these quays. There are plans to build another 1415 m of quay wall, but it is not yet clear when they will start with this part of the plan.

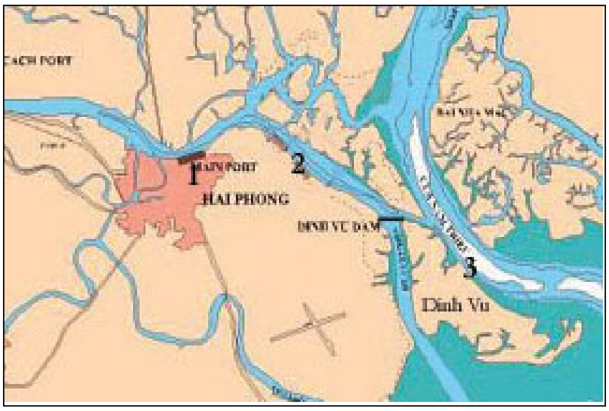

Figure 2.3: neighbouring ports

1 Haiphong main port
2 Chua Ve terminal
3 Dinh Vu port

Cai Lan port is situated in a bay near Hon Gai, which is in a straight line about 38 km northeast of Haiphong (see figure 2.4). This port is still under construction. It can handle ships of 50.000 DWT. The natural conditions for this port are very good; the wind is calm, so are the waves and natural depth is sufficient. Because this port is developed in a bay, extension is not possible. The access channel passes Halong Bay. This bay is a world heritage; measures have to be taken to make sure that the ships will not disturb the ecosystem in this area.

Figure 2.4: Cai Lan port

The other ports in northern Vietnam, i.e. Cam Pha Port (situated just east of Cai Lan port), Hong Gai Terminal (west of Cai Lan), Quang Ninh Port and B-12 Oil terminal, are all special use ports, owned by state oil and coal companies.

2.3 Economy/ demography [10]

The Red River delta's population in 2002 was approximately 17.5 mln, which accounts for 22% of the total population of Vietnam. The Red River delta is considered as one of the most densely populated areas in the world. Haiphong, with a population of 1.74 mln in an area of 1.519 km^2, has a population density of 1.149 persons per km^2. By comparison, the Mekong delta has 400 persons per km^2 and the national average is 241 persons per km^2.
The average GDP per capita in 1993 was US$ 165, respectively US$ 441 in 2002. For the inhabitants of Haiphong City this is much higher, the GDP in 2002 is US$ 763.

38.3% of Haiphongs GDP is earned by industry and engineering (16.5% by agriculture, fishery and forestry and 45.2% by service). This percentage is still growing compared to the service and agriculture percentages.

The trade in Haiphong is growing rather fast lately. The amount of transport going in and out of Haiphong is 23.2 mln tons a year (2002). Table 2.1 shows the import and export figures of the last few years. Main export products are shoes and sandals, garment, pork and carpets. Main import products are cigarettes, electrical products and materials to produce garment, shoes and sandals.

Table 2.1: import and export figures Haiphong

(mln US$)	2000	2001	2001-2005
Export	313	416	471
Import	334	407	429

2.4 General port system in Vietnam up to 2010

The government designed a master plan for the port system of Vietnam up to 2010. This plan was presented in 1999 and gives the following information. The general cargo throughput in Vietnamese ports in 2003 is 106 mln tons per year. For the year 2010 it is estimated to be 200 mln tons per year. The seaport system, which is considered to handle this cargo, consists of 114 ports divided into 8 groups. Haiphong is located in the first group, which contains all seaports from Quang Ninh province to Ninh Binh province. This group is expected to handle an amount of 54-67 mln tons per year.
The maximum ship size that can be handled in Vietnamese ports until the year 2010 is 50.000 DWT (break bulk). This is decided by the government.

The throughput in TEU per year is low in Vietnam compared to other Asian countries, but it is developing rather fast.[15]

Table 2.2: throughput figures Asia

Country	mln TEU/ year			Annual rate of increase	
	1990	1994	2000	1994/1990	2000/1990
Singapore	5.2	10.4	20.6	2.00	3.96
Malaysia	0.9	1.7	3.3	1.89	3.67
Thailand	0.9	1.6	2.4	1.78	2.67
Indonesia	0.9	1.9	3.7	2.11	4.11
Philippine	1.4	2.1	3.6	1.50	2.57
Vietnam	0.1	0.4	1.2	4.00	12.0
Other	-	0.1	-	-	-
Total	9.4	18.2	34.8	1.94	3.70

2.5 Cargo flow and shipping forecast

In this section the expected throughput for the next decades will be determined. Use has been made of several methods concerning the economic growth, import, export and governmental expectations on growth.

2.5.1 Definition of the port's hinterland

The hinterland of the Haiphong port is rather extensive; the captive market is spread out over northern Vietnam, southern China and the northern part of Lao.
Hanoi, the capital of the country, is situated in northern Vietnam. A major part of the transport handled by Haiphong port is destined for or coming from Hanoi and its surroundings. Large industries are located in the north as well, especially producers of garment, shoes and carpets. Another important factor in the cargo throughput is the agriculture. Rice is the dominant crop; 6 mln tons/year are being produced in the cultivated area in the north of Vietnam.

The shortest connection to a seaport for southern China and the northern part of Lao is the port of Haiphong. If the hinterland connections will be improved, these parts of the neighbouring countries can be served as well. The existing hinterland connections and the possibilities to extend them will be discussed in section 2.15.

2.5.2 Surrounding ports in neighbouring countries

Three Chinese ports are situated near the Vietnamese border. The first one is Fang Cheng port, situated 160 km from the Chinese-Vietnamese border. This port handles 5 mln tons per year; the maximum ship size is 10.000 DWT. The Zhangjiang port is located at a distance of 400 km from

Haiphong. This port is number 8 on the list of cargo tonnage of Chinese ports. The Hainan Island Ports are situated on an island 300 km east of Haiphong. On the island an economic zone is developed in which 17 smaller and bigger ports are located.
The existing facilities in China cannot cope with the increasing traffic demand. Congestion exists in most of the major ports, especially in grain, fertilizer and ore transports.
Since these ports are busy serving their own provinces, Haiphong port can serve the south-western part of China without having to compete with these ports too much.
Lao has no seaports, since it has no sea boundaries. The governments of Laos and Vietnam have interred into an agreement allowing Lao to use the port of Danang (in the centre of Vietnam) without paying any charges.

2.5.3 Average annual growth GDP

In 1996 a consortium of AIG, IPEM and AID carried out a feasibility study on the Dinh Vu Economic Zone. For the port & sea sector calculations were performed on the average growth of the transport in northern Vietnam. The calculations indicated that for an average annual Gross Regional Product (GRP) growth rate of 10.6% in northern Vietnam in the period of 1993-2010, sea cargo transport would grow by 1 times the GRP growth annually.
The World Bank presents data on the average annual growth of the Gross Domestic Product (GDP) at her website [28]. GRP figures are not available.
For Vietnam the GDP figures are as follows:

Table 2.3: GDP growth figures Vietnam

(%)	**1991-2001**	**2000**	**2001**	**2001-2005**
GDP	7.7	6.8	6.8	7.0

An initial master plan study for the deep-water port of Haiphong[15] presents the following figures:

Table 2.4: GDP figures initial master plan Haiphong

(%)	**2001-2005**	**2006-2010**	**2010-2020**
GDP	7.7	6.7	6.5

The mean statistic indicator of Haiphong, provided by the Haiphong Statistic Department published figures of the GDP growth specified for Haiphong. These figures do not include the growth of the population, so the actual growth of GDP per person will be lower, because the population will grow as well. Statistics on the estimated population growth are not available.

Table 2.5: GDP figures mean statistic indicator

(%)	**2000**	**2001**	**2002**	**2003-2005**
GDP	9.1	10.4	10.6	10.5-11.0

Although the figures differ somewhat, it can be said that the GDP growth percentages for Haiphong are higher than for other parts of the country. The same applies for Hanoi. The average annual GDP growth of Hanoi was 11.6% for the period 1991-2000.
Although Hanoi and Haiphong are two of the major cities to be served by this port, it is not realistic to use their GDP figures to calculate the expected growth of cargo in the Haiphong port. Other parts of the hinterland have a much lower GDP growth expectation. For this reason the figures of the Worldbank (table 2.3), who represent the whole country will be used for the calculations in section 2.5.5.

2.5.4 Cargo throughput last ten years

The throughput figures of the last ten years give a perception on the way the port has been developing. The influence of the changing economy is also apparent. The foreign trade has grown rapidly the last few years, which can be seen from the import and export figures. The greatest development in container transport was in the early nineties, when the growth percentages were over 50% per year. Domestic transport mainly consists of transport in between Ho Chi Minh City and Haiphong/ Hanoi (intracoastal).

Table 2.6: Haiphongs cargo throughput statistics from 1991-2001[14]

Year	total volume (1000 tons)	growth (%)	among which (1000 tons)			container share (TEU)	growth (%)
			export	import	domestic		
1991	2433	-	409	621	1403	20991	-
1992	2378	-2.3	382	849	1084	35638	+69.8
1993	2706	+13.8	416	1176	1115	55956	+57.0
1994	3249	+20.1	441	1702	1107	91860	+64.2
1995	4515	+39.0	494	2362	1660	117636	+28.1
1996	4809	+6.5	655	2440	1715	149100	+26.7
1997	4588	-4.6	783	2270	1497	165351	+10.9
1998	5446	+18.7	850	2618	1978	183805	+11.2
1999	6510	+19.5	939	3170	2400	198799	+8.2
2000	7645	+17.4	1234	3586	2825	219000	+10.2
2001	8575	+12.2	1336	4358	2882	228000	+4.1
2002	10350	+20.7	1400	5370	2882		

2.5.5 Cargo throughput forecast

Three different ways have been used to estimate the cargo throughput for the Haiphong port region in the next few years. These methods can be found in Appendix I.
The cargo throughput has been calculated related to the GDP growth and the expected growth of the im-/export volumes. Furthermore the government's expectations have been used on cargo throughput in the seaport system of the whole country. The throughput expectations for the neighbouring ports will be subtracted, in order to calculate the cargo flow in Haiphong deep-water port.
From these calculations, the design throughput will be determined.

Containerisation
Since the containerisation rate for cargo worldwide is still about 55%, there is room for container throughput to rise even when global trade volume remains stagnant. This is especially the case for developing countries where the containerisation rate is well below the international level. VINAMARINE (Vietnam National Maritime Bureau) expects the container throughput to grow by approximately 10% annually for the period 2010-2050. So the container throughput will grow relatively fast compared to the general cargo. The new port will mainly focus on container transport. Therefore the containerisation rate for the deep-water port will be higher than it is in the existing port of Haiphong.

Conclusion
The following table summarises the above-mentioned calculations:

Table 2.7: different throughput calculations

	Source	Throughput (tons)	
		Haiphong port	Deep-water port
2005	GDP	11.240.076	-
	Im-Export	11.325.444	-
2010	GDP	15.545.022	7.045.022
	Im-Export	15.959.897	7.459.897
	Government	30.650.000	22.150.000
	Maritime bureau	17.250.000	8.750.000
2020	GDP	29.180.143	20.680.143

A throughput capacity for the deep-water port of 7.5-8 mln tons in the year 2010 seems to be the most realistic expectation.
For the year 2020 only one source is available; this makes it hard to verify if this expectation is correct. Since the expectation based on GDP growth for 2010 is slightly below the average, the expectation for 2020 might be so as well. The expected growth of the containerisation rate is another reason to enlarge the expected amount of cargo for 2020. Even though the global trade volume may grow steadily, it can be expected that a larger volume of cargo will be transported in containers, which is an advantage for the new deep-water port in Haiphong. Assuming a containerisation rate of 30%, a

growth percentage of 10% for the container throughput, the GDP prediction for 2010 and an expected growth of 6.5 % for the general cargo, the expected cargo throughput for 2020 will be about 24 mln tons for the deep-water port. That is slightly higher than the expected 20.7 mln tons when the extra container growth is not encountered.
Therefore the margin of the throughput in 2020 will be taken a little ample, 20-25 mln tons. During the design phase it must be kept in mind that these are just rough expectations and that it is good to save some space for future possible extension.
In the figure below the expectations for 2005, 2010 and 2020 are given for the different sources. The left columns reflect the expected throughput of the complete Haiphong port. For the years 2010 and 2020 the throughput is split up in the expected throughput for the deep-water port (middle columns) and for the existing port (right columns). The maximum throughput for the existing port is 8.500.000 tons.
This figure shows that the expectation of the government for 2010 is much higher than the other sources.

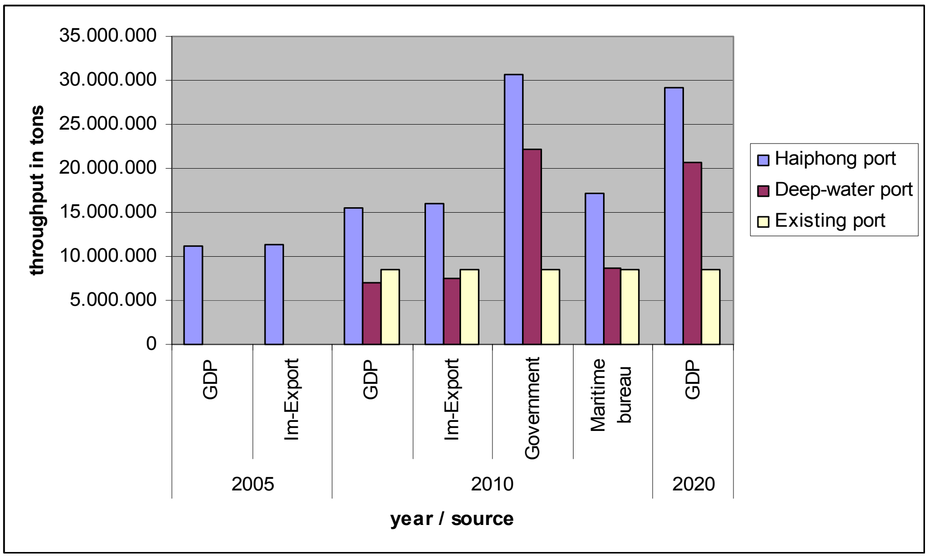

Figure 2.5: throughput expectations per year for different sources

2.5.6 Vessel type

The Vietnamese government would like the Haiphong deep-water port to be able to accommodate 80.000 DWT vessels and container ships with a capacity up to 6000 TEU. It is questionable though, if there is a market demand for a port with these facilities. The 80.000 DWT vessels now visit the ports of Singapore and Hong Kong; two large ports which are located in Southeast Asia as well. From there the cargo can be transported in smaller vessels to the surrounding countries. It will be hard to compete with these ports, especially because Haiphong is not optimally connected to an existing sea-route and the Gulf of Tonkin is not very deep.

Although Haiphong port wants to serve a rather large hinterland, it is not proved that it is necessary to use the large 80.000 DWT ships to transport the cargo. These ships require a lot of expensive facilities and on top of that the access channel should be quite deep.
It might be better to concentrate on the facilities for vessels that are a bit smaller. They can serve as a hub between the ports of Hong Kong and Singapore and the hinterland of Haiphong. Furthermore a shuttle service can be developed between Haiphong and Ho Chi Minh City. This coastal service could be in charge of all the transport from north to south and vice versa.

It seems more useful to invest the available money and capacity in a port, which can accommodate ships with a maximum capacity of 50.000 DWT, instead of constructing quays for 80.000 DWT ships. For the container ships a maximum capacity of 3000-4000 TEU seems reasonable. The general cargo ships will be even smaller; the main focus will be container ships.
The size of 50.000 DWT has been chosen, because the same size of ships is going to be handled in the new port that will be constructed in Ho Chi Minh City. The intracoastal transport can only get started when both ports can handle the same ships. Besides, Cai Lan port is designed to handle 50.000 DWT vessels as well, so if a smaller design vessel will be chosen, the ships will flee to Cai Lan

port. Another important reason is that the largest Panamax vessels, which are still very popular, can be handled when the port is dimensioned on a design vessel of 50.000 DWT.
For general cargo, 30.000 DWT as maximum ship-size seems to be large enough, especially because the general cargo will be shipped in the region mainly. Other ports in Vietnam and the surrounding countries also do not have the facilities to handle too large vessels. The old port of Haiphong can handle all the smaller general cargo vessels (up to 10.000 DWT). They have the facilities to do that. The vessels of 20.000 and 30.000 DWT can be handled in the new port.
In the future, when the Haiphong port authority is able to manage this new port and the Vietnam economy keeps on growing steadily and fast, it might still be possible to deepen the access channel and the port to make it able to serve larger vessels.

Design vessel Post-Panamax

L	270-300 m	Capacity	4.300-4.600 TEU
B	38-40 m		54.000 DWT
D	12.0 m		

Design vessel General Cargo

L	186 m	Capacity	30.000 DWT
B	27 m		
D	11.0 m		

2.6 General Climate of Haiphong[2, 6]

Haiphong has a tropical climate with high humidity and high temperatures. The average yearly rainfall is 1760 mm (deduced from a period of 76 years). The rainy season covers the months May to October; this period occupies 75-85% of the total yearly rainfall volume. The months October to December are particularly foggy. Twenty days a year the visibility is less than one km.
Earthquakes rarely occur in Haiphong. The local seismic map indicates that this belt area belongs to a seismographic zone with a magnitude of 6.1 to 6.5 on the Richter scale.
Cyclonic storms in the area are depressions, tropical storms and typhoons depending on wind speed. Most originate from the east of Philippines, but some come from further west in the South China Sea. An average of three to four typhoons strikes the coastal area annually. However, the frequency of storms and typhoons appears to have increased in recent years. The typhoons bring strong winds, heavy rainfall (over 100 mm/day) and storm surges accompanied by large waves. The typhoon “Sarah” struck the Haiphong port area in 1977 with the highest wind speed recorded being 180 km/h.
In spite of the apparent severity of the typhoons, however, it should be noted that Haiphong is situated behind Hai Nan Island acting as a measure of protection for most of the typhoons striking northern Vietnam. In addition, the coastal formation of the area provides good shelter and reduces the force of the typhoons. The damage due to the typhoon in the Haiphong area is consequently less than that experienced in other parts of the country.

2.7 Winds

The climate is mainly influenced by the monsoon winds of East Asia, the northeast monsoon prevailing from November to April, and the southeast monsoon prevailing during the remainder of the year.
At the island Bach Long Vy, situated in the middle of the Gulf of Tonkin, measurements have been taken at a meteorological station 72 m above sea level, to analyse the offshore wind climate. From 20 years of data collection in the period 1976-1995, the following parameters represent the yearly averaged wind climate[20]:

Table 2.8: yearly averaged wind climate

Percentage of time	Wind speed
70%	< Beaufort 4
85%	< Beaufort 5
95%	< Beaufort 6

The average wind speed is equal to Beaufort 3.5. These figures are almost the same for winter and summer monsoon. The direction on the other hand varies per season (see Appendix II for a wind rose):

Table 2.9: wind direction and speed

Season	Main directions (% of all directions)	Wind speed (highest)
October-April	NE (60%) E (20%)	Beaufort 9 N/NE
May-September	S (40%) SE (10%) SW (10%)	Beaufort 9 S

The strongest winds with speed Beaufort 12 (typhoon conditions) have occurred in the period 1976-1995 in June, August and October.
On the basis of statistical figures on wind and waves at Hon Dau (through the years 1960-1994), the level of rising water caused by storms at the studied area can be determined. In 30 years rising water of over 1.2 m high arose 52 times, this means an average of almost two times a year of rising water of over 1.2 m high in Doson and the vicinity.
Almost all the storms that crash into the area bring along heavy rains, which cause heavy erosion to hill slopes at Doson and bring alluvium to bathing beaches.

Typhoons are normally accompanied by storm surges, wind set ups and wind waves. The strong typhoon winds generate large waves and increase the water level even more by wind set up. During the last 30 years half of the recorded typhoons caused a storm surge over 1 meter high and 11% over 2.5 meters high. It can be expected that a very rare typhoon may cause a surge several meters high.

2.8 Waves

The dominant wave direction varies; depending on the season the waves originate from the northeast, through east, to south and southwest. On an annual basis one can say that the northeast direction dominates. However, in summer typhoons strike the coast; they usually appear from the south and southwest.
Because of the great differences per season the main characteristics of every period have been described in Appendix III. These characteristics have been deduced from Global Wave Statistics[11]. The data for area 40 are used; these describe a rather larger area, covering the entire Vietnamese coast and the southern coast of China.

Striking is that the highest maximum waves have not been measured in the stormy season (June-July), but in the autumn and winter months. In these months the wave period is a bit longer and the main wave direction is NE. During spring the wind starts to turn to the south and the wave period decreases. In summer the wind blows from the south and even southwest and the waves are rather low.
Because the data from the Global Wave Statistics cover the whole south Chinese sea and are measured far offshore, it is necessary to specify the data in more detail. Therefore the site of Argoss[26] has been consulted. An area of 50*50 km around Doson peninsula was selected. (20°40'N, 106°49'E)

Monthly distribution of sign. wave height (m)													
lower	**upper**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
0.0	**0.5**	22.1	19.6	31.2	29.7	23.2	3.2	9.6	25.0	32.4	28.8	26.2	22.2
0.5	**1.0**	45.6	52.9	31.2	37.5	40.6	41.3	43.8	38.9	47.1	38.4	37.5	49.4
1.0	**1.5**	17.6	17.6	18.8	21.9	24.6	46.0	27.4	29.2	11.8	21.9	26.2	21.0
1.5	**2.0**	13.2	5.9	12.5	7.8	7.2	7.9	8.2	0	4.4	6.8	8.8	2.5
2.0	**2.5**	1.5	3.9	4.2	3.1	4.3	1.6	8.2	2.8	2.9	0	0	3.7
2.5	**3.0**	0	0	2.1	0	0	0	2.7	2.8	0	4.1	1.2	1.2
3.0	**3.5**	0	0	0	0	0	0	0	1.4	0	0	0	0
3.5	**4.0**	0	0	0	0	0	0	0	0	1.5	0	0	0
4.0		0	0	0	0	0	0	0	0	0	0	0	0
total		100.0	99.9	100.0	100.0	99.9	100.0	99.9	100.1	100.1	100.0	99.9	100.0

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Figure 2.6: monthly distribution of significant wave height

This figure shows that the average for the month June is slightly higher than the other months and that for the month September the highest waves have been measured.

The histogram results for the whole year have been compared with the results for June-September. This can also be found in the Appendix III.
It can be seen that the extreme values for the wave heights in summer are a little higher, but the differences are very small. Compared to the data of the Global Wave Statistics, it is remarkable that the significant wave height is a little lower. This can be explained, because Doson is located in a rather sheltered area (especially when the wave direction is northeast).

A table which compares the wave direction to the wave height in an area of 200*200 km is added to Appendix III and so is a web that indicates the main wave directions.

<u>Conclusion</u>
Although it is difficult to draw a univocal conclusion from above data, it seems clear that a significant wave height of 0.5-1.5 m is reasonable to assume as an operational condition. The probability of exceedance of this height is 10% according to Argoss (see table III.2 in Appendix III). The direction differs somewhat, but it can be concluded that there are two main directions, namely NE and S/SW. This differs per season and both should be taken into account. The Global Wave statistics mention that wave heights of 8-10 meters have been measured at the south Chinese sea. However in an area of 50*50 km around Doson peninsula a wave height of 2.9 m in the stormy season (June-September) has a probability of exceedance of only 1% (according to Argoss, table III.2 in Appendix III). It seems reasonable to base the calculations for Haiphong port on this result.

2.9 Hydraulic data

The two most important hydraulic aspects are the influences of tides and currents. Both will be discussed in the next two subsections.

2.9.1 Tides

In the coastal zone near Haiphong the tides are diurnal with a spring tide/neap tide cycle of 14 days. The tidal wave propagates from south to north with mean velocities between 0.2-0.3 m/s. The maximum ebb-tidal current is 0.6 m/s and the maximum flood-tidal current is 0.5 m/s.[13]
Figure 2.6 shows a tidal prediction for Hon Dau station (water level measuring station 20 km south of Haiphong).

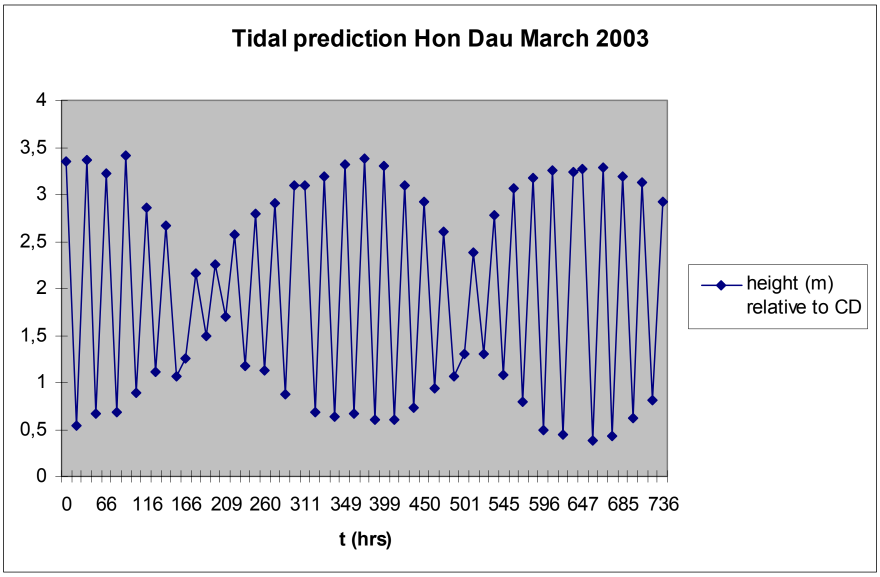

Figure 2.7: tidal prediction Hon Dau station

This figure only shows data of one particular month (March 2003), shortly after which the tidal station was visited. It does give a view on the regular tide pattern though. In table 2.10 tide characteristics are shown.

Table 2.10: tide characteristics Hon Dau station

P%	1	3	5	10	20	50	70	90	95	97	99
H_{high}	3.8	3.7	3.6	3.5	3.4	3.1	2.8	2.4	2.2	2.2	2.0
H_{low}	1.9	1.8	1.7	1.6	1.4	0.9	0.7	0.5	0.4	0.4	0.3
$H_{average}$	2.4	2.3	2.2	2.2	2.1	2.0	1.9	1.8	1.8	1.8	1.7

H_{high} Highest water level
H_{low} Lowest water level
$H_{average}$ Average water level

2.9.2 Currents

In this area of the Gulf of Tonkin the diurnal tide current plays the main role, the semi-diurnal tide current is only noticeable in low tide days. The tide current into the estuary is under the form of a wedge (salty wedge form), hence in many cases the surface currents have the direction from the river to the sea while bottom currents are of the direction from the sea inward.

Although clear figures are not available, from several talks with different organisations the assumption can be made that there is no current to speak of in the Cam River. The currents in the Bach Dang River section of the access channel to Haiphong port are not severe enough to cause any problems with navigation or berthing.

2.10 Bathymetry

For the bathymetry survey the British Admiralty Chart 3875 is used. This map gives a detailed survey of the water depths compared to Chart Datum. Near the mouths of the different rivers, the water depths vary from 0 to 5 meters. The bottom of the sea mainly exists of mud. The land near the coast consists of many ponds that regularly flood. The ponds are surrounded with low dykes and embankments that hardly protect them against the rising water.
Many sand banks are found in this area. Appendix IV describes the formation of sand banks in this area and shows 2 maps of the sandbanks near both locations.

2.11 River characteristics Red River Delta

The Red River is the second largest river of Vietnam after the Mekong River in the south. The total catchment of the Red River covers 169.000 km^2, of which 87.000 km^2, including the delta are in Vietnamese domain. The delta of the river is a flat, alluvial plain with over 50% lower than 2 m above

sea level. The volume of flow in the Red River is approximately 122 billion m^3 per year and its sediment load is about 100-114 mln tons[4]. This amount of sediment is the same as in the Mekong River, although the Red River only carries a quarter of the amount of water of the Mekong.
Several rivers flow into the Gulf of Tonkin near Haiphong. From south-west to north-east these are: River Van Uc, Lach Tray River, Cam River, Nam Trieu River and Lach Huyen River [see map Appendix VII]. The amount of sand that is carried to sea is very large. Table 2.11 shows the amount of sediment transported by each river per year.

Table 2.11: sediment transport in rivers Red River Delta

River Estuary	Sediment (mln tons/year)
Lach Huyen	0.4
Nam Trieu	3.2-4.2
Lach Tray	0.6-0.7
Van Uc	6.4

This sediment contributes to the formation of the sandbanks at the estuaries and to the coastal muddy sand current. The muddy sand of the estuaries carried to the sea in summer amounts to 86% of the muddy sand volume in a year.

The analysis of bed samples collected in and around the navigation channel clearly demonstrated that the channel material is mainly mud. Some patches of sand occur on the bank adjacent to the channel, but sand is not thought to contribute significantly to channel sedimentation.
A large amount of sediment is carried down the Cam River and has been diverted by the Dinh Vu Canal and Dam so that it flows through the Nam Trieu estuary to be deposited in the area of the dredged access channel.

In the year 1986 the Trap Canal was constructed. This channel connects the rivers Nam Trieu and Lach Huyen. It is planned to dredge it to a depth, which makes it possible to use it as part of the new access channel to Haiphong port in 2005. In this way, the ships can make use of the deeper Lach Huyen River instead of the Nam Trieu River. The amount of sediment at Lach Huyen estuary is relatively small compared to the amount of sediment in the Nam Trieu estuary.

2.12 Geotechnical aspects/ soil data

Some data are gained from surveys of the formal USSR, TEDI, HAECON (Belgium) and Haiphong port. Seismic research and a soil survey were done in the area near the mouth of Nam Trieu and Cam rivers. Only two holes were drilled, each with a depth of 80 m.
The cover layer is Halocen sediment, it is soft and this layer has an average depth of 30 meters. The next layer is Pleistocen sediment, stiff clay with an average depth of 30 meters. Underneath a layer of hard stone from the Devon period was found.

2.13 Regional planning

The population of Cat Hai Island is 20.000 with a density of 660 people per km^2. The main economic activities are rice production, fishing, salt production and other sea-based industries. The island is regularly threatened by typhoons and storm surges, which submerge paddies and houses and damage infrastructure every 2 to 3 years. The waves also threaten to undermine the shore protection structures.
The road system at Cat Hai Island is not developed at all, neither is there a railway connection. Only a ferry connects this island with the mainland of Haiphong.
Power supply is available, only some fishermen still use rechargeable batteries and diesel generators. The water supply is rather poor. Families use big tanks to collect raining water for cooking and drinking. Only a few bigger families own private wells.

At the location south of Doson lives a small community of 1000 people. Most of them are fishermen with their families. Part of the land is used for breeding of seafood. No industry is located in this area, neither is there a lot of agriculture because the land is infected by the salted water. A small part of the land floods during high tide.
Power is available, like it is at Cat Hai Island. Water for drinking is also collected from raining water and can be bought at nearby water stations. The fishermen also use water from the river.

There is a small road that connects the village with the just rebuild road from Doson to Haiphong. A railway connection is not nearby.

2.14 Environmental/ safety aspects

When developing a port, it is obviously that the environment has to be reckoned with and so is all the legislation on the safety field.
The legislation on safety and environment in Vietnam are according to the international standards and will not be mentioned in particular here.
One part of the government's development strategy will be mentioned, because it especially involves Ha Long Bay, the area near which Haiphong is located. The development strategy of the port and sea transport sector prescribes that in the development of a new port it has to be taken into account that the existing environment and traditional cultural entities of the Gulf of Tonkin in general and Ha Long Bay specifically will be protected, given their great importance as a long-time historical heritage and to the tourism industry.
Another point of attention is the possible needed extensive dredging. This can have a huge influence on the fishing habitat in this area. Further research on this subject has to be done. In the next section the environmental consequences of landfill and levelling will be discussed in short.

2.14.1 Environmental elements on landfill and levelling[19]

Landfill and levelling are necessary in case of developing a port. This implies that a number of areas where sand is borrowed, transported through, and put down, will be affected and so are various environmental elements.
For the borrowing area attention should be paid to:

- Sea water quality, especially turbidity and effects due to sediments being stirred;
- Aquatic ecosystem, of which fishing fields, fish spawning areas and effects due to the exploitation of other aquatic species should be paid special attention.
- Changes in the erosion-sedimentation balance in the area, due to the borrowing of a quite large volume of sand.

The safety of the channel on which the sand is transported will mainly be affected by the increased traffic, whereby the possibility of incidents that occur will enlarge.
On the spurted land attention should be paid to the quality of air, especially dust, noxious gases, noise and the ecosystem. In the surroundings of the new land it must be kept in mind that the water quality and the aquatic ecosystem do not decline.

The process of borrowing a rather big quantity of sand during a rather long period will bring about by-effects, which change the sea bottom terrain and lead to the change of currents and the erosion-sedimentation process in the area. The sand borrowing will break the silt-sand balance and bring about changes to the erosion phenomena in certain areas and sedimentation phenomena in a number of other areas.

The process of implementing a new port will bring about a number of effects to natural resources and ecological environment in the area. Among those, utmost attention must be paid to the impact on bottom fauna, aquatic product catching productivity, quality of seawater in the area, change of the balance of sedimentation in the area leading to the change of the erosion-sedimentation phenomena in the area. On the new port location there will be dust and increase of toxic gases originating from landfill and levelling activities.

2.14.2 Safety aspects

One of the measures that can help improving the safety of the access channel is one-way traffic. During the design phase it has to be investigated if a one-way traffic system is sufficient. This depends on the expected number of vessels. A good traffic control system will be of great influence on the safety as well.
All other safety measures (navigational aids, tugboat assistance, pilots etc.) are of great importance, but will be organised in a later stage of the study.

2.15 Hinterland connections

As discussed in section 2.5.1, the hinterland of the Haiphong port is rather extensive; the captive market is spread out over northern Vietnam, southern China and the northern part of Lao. Further more Haiphong has good sea connections with other south-east Asian ports. Table 2.12 shows some of the distances to important cities in south-east Asia. From this table it is clear that the overseas connections are the shortest.

Table 2.12: distances to other south-east Asian destinations by different means of transport

Regions	Sea route (km)	Road (km)	Railway (km)
Ho Chi Minh	1480	1800	1926
Danang	560	965	890
Hong Kong	910		
Manila	1620		
Singapore	2670		
Tokyo	4350		
Nanning (China)			2966
Kunming (China)			765

The Worldbank presented figures on the freight ton-kilometres in Vietnam.[4] These figures show that especially the intracoastal waterways have developed strongly in the nineties. The vast majority of Vietnam's long haul low-value domestic freight moves by "ocean" or intracoastal water, for which the north-south bulk commodity shipments are ideally suited. The intracoastal water has captured the major share of longer-haul Vietnamese bulk freight traffic.

The existing Haiphong port uses the following transport mode to convey the cargo:

Table 2.13: means of transportation to the hinterland

Port	Road (%)	Rail (%)	Inland waterway (%)
Main port of Haiphong	70	20	10
Chua Ve terminal	85	10	5

The main mean of transport is by road, this is partly because the road to Hanoi (Highway no. 5) has been improved lately and partly because the rail connection is not yet extended to the Chua Ve terminal.

In the next sections the different means of transport and the possibilities to extend them will be discussed.

2.15.1 Road

The most important road of this zone is Highway No.5, which connects Dinh Vu with Chua Ve Terminal - Haiphong main port – Hanoi.
The distance Haiphong - Hanoi is 102 km, and this road connects Haiphong with other important road links from Hanoi. One of these road links is Highway no. 1, which connects the Chinese border, via Hanoi and Ho Chi Minh City, with Cau Mau Cape in the very south of the country.

The road connections from Haiphong to both possible locations are not good. To Cat Hai there is no road at all at the moment, the only way to get there is by ferry. To get to the point where the shortest connection is with the mainland, a road of 15 km (including one smaller bridge) and a bridge of at least 1150 meters (crossing the main access channel to Haiphong port) must be constructed, ending on Dinh Vu Peninsula. From there the trucks can get to Highway No. 5.
The road to Doson has just been rebuilt. It only needs to be connected to the area south of Doson; this will be, depending on the exact location, about 2.5 km.

2.15.2 Railway [21]

Vietnam Railway is similar to most of the railways in the formerly socialist, planned economies. In the absence of effective competition, Vietnam Railway operated well enough physically and financially to survive, but it is not familiar with linkages among cost, quality and demand for its services. The main short-term physical problems are related to its large number of deteriorated bridges, some of which are currently under repair. Vietnam Railway's traffic density is low, indicating the presence of under-utilised tracks. The railway system in Vietnam appears to be two, one in the north, another in the south, with very little traffic interchanged between them.
Despite the problems faced by Vietnam Railway, its freight traffic has grown more lately than in any of the other smaller Asian countries.

Haiphong-Hanoi-Lao Cai-Kunming, the international railway line between Vietnam and southern China has been revitalised and provides reliable transportation services to these locations. Kunming gives access to the national railway system of China.
There is no railway connection to Lao and as far as it is clear now, there are no intentions to construct any.

For the railway connections to both possible locations counts the same as for the road connections. There is nothing constructed yet in both areas. From Cat Hai the railway has to go along the same path as was chosen for the road. The railway can access the main railway system at the Dinh Vu peninsula, since a railway extension from the existing railway at Haiphong Port to Dinh Vu is expected to be operational in 2005.
There is no railway going to Doson or to any other place in that direction. The distance between the railway in Haiphong and the location is about 20 km (following the same path as the road).

2.15.3 Inland waterways

Vietnam has 41.000 km of inland waterways extending to almost all populated areas and industrial zones. Of this amount, about one-quarter can support year-round transport, and only one-tenth (4000 km) has sufficient drafts to carry large commercial vessels. Twenty-three major river ports handle bulk cargo and numerous small, private facilities handle smaller loads.
Waterway capacity and safety have declined in recent years due to several factors, including the silting of channels, continuously changing alignment and depth, inadequate navigation aids (navaids), sharp bends and other obstacles. Severe silting has resulted from a dredging backlog estimated at 25 mln cubic meters (10 mln in the north and 15 mln in the south). The dredging fleet is old and in poor condition and so is the fleet of inland water vessels. There are no funds for renewal at the moment.

The Cat Hai location is situated in between the rivers Nam Trieu and Lach Huyen, hence there are many opportunities to use both rivers as an inland waterway connection.
The location south of Doson is situated just north of the river Van Uc. To get to Haiphong main port and its hinterland, the vessels have to go back seawards, pass the Doson peninsula and then enter the river Nam Trieu.

2.15.4 Air

The Cat Bi airport is situated near Haiphong. This airport is currently used for domestic flights connecting Haiphong with Ho Chi Minh City and Danang. The Cat Bi Airport is now considered to be a supporting airport to Hanoi's Noi Bai airport. International flights within the region are planned to use Cat Bi Airport in future, connecting Haiphong to international routes.

2.15.5 Feeder services

There are no direct shipping routes in Vietnam to North America or to Europe. From Haiphong port and Ho Chi Minh City there are the following feeder service routes:

Ho Chi Minh City - Haiphong - Hongkong - Taiwan - Korea - Japan

Haiphong - Ho Chi Minh City - (Bangkok) - Singapore

For both above mentioned routes Haiphong and Ho Chi Minh City only function as a feeder port.

2.15.6 Conclusions hinterland connections

Haiphong is connected to its hinterland by all means of transportation. The quality of the existing connections is not very good though.
The lately reconstructed Highway No. 5 is new, but very crowded already. When the container transport through Haiphong will increase, a lack of capacity will arise on this road. The railway and the inland waterways need the time to take necessary measures before having complete control of the container transport as today they lack capacity and facilities to take over to ease Highway No. 5's increasingly heavy road traffic from cargo on route between Haiphong port and Hanoi. The inland waterway ports will need funding to be able to invest in their equipment and fleet. The same counts for the dredging companies. Another very important point of attention is the safety on the inland

waterways. This should be improved before enlarging the traffic on the rivers; otherwise even more dangerous situations will occur.
National Government's transport policy promotes transport by rail and inland waterway and will try to improve it as soon as possible. International support will be necessary however.

2.16 List of requirements

Functions of the port:

- Primary
  - Traffic function
  - Transport function
- Secondary
  - Industrial activities
  - Commercial and financial services

The new Haiphong deep-water port has to be located at one of the two following locations:

- South of Doson peninsula, just north of the River Van Uc mouth.
- Cat Hai, the land that is situated in between the mouths of the rivers Nam Trieu and Lach Huyen.

Other locations are not desirable.

The new port has to be able to serve the hinterland, consisting of northern Vietnam (including the capital Hanoi), southern China and northern parts of Lao. It can function as a transportation hub for the central and southern parts of Vietnam as well.

The main elements of the port must consist of:

- A safe and accessible entrance channel with sufficient depth
- A port basin with adequate space for manoeuvring and berthing of the ships
- Handling and storage capacity and equipment
- Hinterland connections
  - Rail
  - Road
  - Inland waterways
  - Air

Safety aspects: the port must comply with all the international standards for nautical safety, namely nautical aids, pilot assistance and tugboats; a Vessel Traffic Service is desirable.

Cargo throughput

- Expected type of cargo: container and general cargo, gas and oil is desired in future
- Expected throughput capacity deep-water port
  - 2010 7.5-8 mln tons
  - 2020 20-25 mln tons
    Of which 70% will be handled by containers and 30% will be general cargo.

The port will be operating 24 hours per day. The Vietnamese government wants all ships to be able to enter the port during the entire day. This means that there will be no tidal window. It still has to appear if this is feasible.

The following natural side conditions have to be reckoned with:

- Oceanography (wave climate)
- The dominant wave direction is south and the average wave height is 0.6-0.8 m. The wave period is 6 seconds.
- The prevailing wind directions are NE, E and S with an average wind speed equal to 3.5 Beaufort. Three to four typhoons strike the coast yearly. They are usually accompanied by storm surges, wind set ups and wind waves.
- Hydraulics (tides and currents): the tide is diurnal. The tidal difference is about 2.5 meters. Currents may not complicate the manoeuvring and berthing of the ships.
- The bottom mainly exists of mud. The first layer on which quays possibly can be founded is at a depth of 40 meters.

The following utilities are necessary for a well functioning port:

- Water supply 30 m^3/ha-day
- Power supply 0.37 MW/ha
- Telecommunications

In the development of a new port, it has to be taken into account that the existing environment and traditional cultural entities of the Gulf of Tonkin in general, and Ha Long Bay specifically, will be protected. This is necessary, because of their great importance as a long-time historical heritage and for the tourism industry.

The estimated lifetime of the project is 50 years.

Assumption made after interviewing several consultants

- There is no current to speak of neither in the River Cam nor in the River Nam Trieu and River Van Uc .

3 Dimensions and location determination

3.1 Introduction

On the basis of the in chapter 2 determined cargo throughput and vessel type the required quay length, all terminal facilities and the water area will be calculated in this chapter. A very rough layout will be designed, which will be worked out in more detail later on in this study. For now it is important to determine the most feasible location for the new deep-water port. Two variants will be overlooked in this chapter, namely Cat Hai and Doson. After designing two different sub-variants for each location a Multi Criteria Evaluation will be carried out in the last section of this chapter to determine the most suitable location. The next chapter will go into a more detailed layout of the chosen location.

3.2 Number of berths

In this section the required number of berths and the quay length will be determined using the queuing theory.

3.2.1 Queuing theory, introduction

It is expected that the total throughput for Haiphong in the year 2020 will be 33.5 mln tons (old port and new port, see section 2.5.5). The goal of the Vietnamese government is to handle around 70% container cargo (23.5 mln tons) and 30% general cargo (10 mln tons) in Haiphong port. Of the 10 mln tons of general cargo, around 8.5 mln tons will be handled by the old port, which is constructed to handle this kind of cargo. The odd 1.5 mln tons will be handled in the new port, together with the remaining 23.5 mln tons (or 1.566.667 TEU) container cargo.

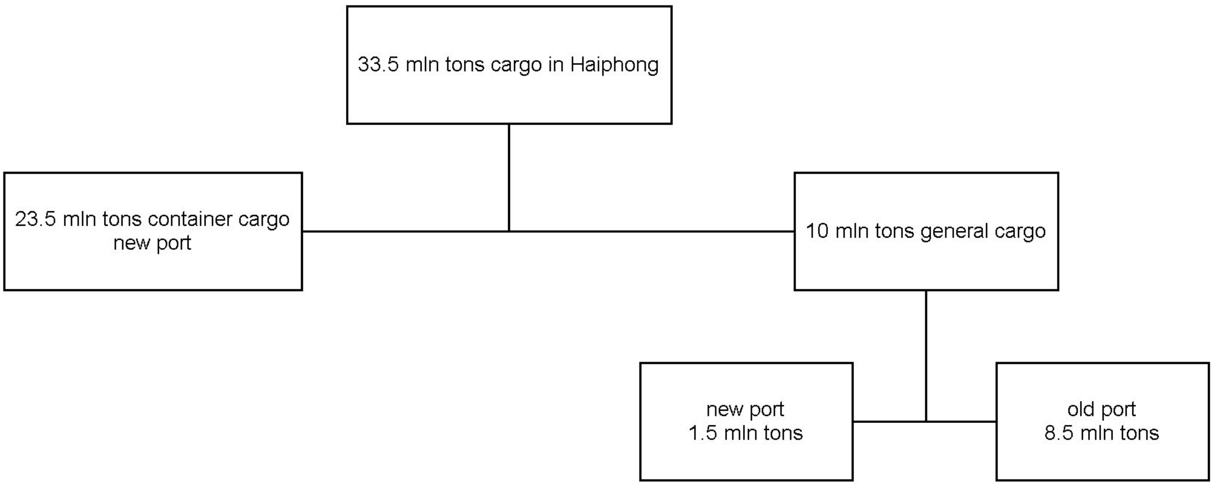

Figure 3.1: cargo distribution Haiphong port, 2020

For the year 2010 it is expected that a total amount of 8 mln tons of container cargo will be handled by the new port. This corresponds with 533.333 TEU. In 2010 the old port is still able to handle the expected amount of general cargo.

It is difficult to calculate the quay length in detail in this phase of the study, because yet so little is known on the arrival of ships. Therefore a first approximation of the number of berths and hence the quay length is made on the basis of the queuing theory. Assumed is that the queuing discipline can be taken as first in first out (FIFO). First the required number of container berths will be calculated.

3.2.2 Container berths in 2020

Production (in TEU) per year per container berth with maximum capacity:

$$\mu = t_n * N_b * p * f$$

t_n	=	*operational hours per year*	*[hrs/yr]*
N_b	=	*number of cranes per berth*	*[-]*
p	=	*gross production per crane*	*[moves/hr]*
f	=	*TEU factor*	*[-]*

For this port the following values will be taken:

t_n	=	*24 hrs/day * 360 productive days/year = 8640 hrs/yr*
N_b	=	*4 cranes per berth*
p	=	*25 moves/hr*
f	=	*1.38*

The service time that is necessary to moor the vessels should be taken into account as well. This corresponds with approximately 10% of the time that a vessel is at the quay. This will decrease the gross production per year per container berth. Therefore the gross production per crane will be cut back by 10% and will now be 22.5 moves/hr.

$$\mu = 24 * 360 * 4 * 22.5 * 1.38 = 1.073.088 \quad TEU / yr$$

μ is the total amount of TEU that can be handled per berth per year. Each vessel will have an average capacity of 4000 TEU, however it will not load and unload the total capacity. Therefore it is assumed that X TEU of every vessel will be handled in the port. It seems reasonable to take a value for X that is around 50% of the total capacity. In this case that would be 2000 TEU for unloading and another 2000 TEU for loading.

μ should be divided by the number of TEU that need to be handled per vessel (X). With above-mentioned assumption X would be 2000 + 2000 = 4000 TEU.

$$\mu = \frac{1.073.088 \quad TEU / yr}{X \quad TEU / vessel} = \frac{1.073.088}{X} \quad vessels / yr$$

Expected amount of container cargo for the year 2020 exists of the following: the expected throughput (1.566.667 TEU) and containers that leave the port empty. The assumption has been made that the division of the im-/ export figures is the same as for the year 2010 (see section 2.5.5). The expected throughput is subdivided as following (see below for the modal split, figure 3.2):

70% import	Containers arriving by vessel from overseas and departing to the hinterland: 1.096.667 TEU
12 % export	Containers arriving from hinterland and departing by vessel: 188.000 TEU
18% domestic	Containers arriving from industrial areas in northern Vietnam (by road or rail) and transported by vessel to the southern part of Vietnam, or the other way around. It is also possible that the container arrives by vessel from a Vietnamese port and will be transported by vessel to another Vietnamese port as well. In this case two crane-moves should be counted. This situation will not often occur though, because Haiphong is one of the most northern ports, so over sea they will hardly go further to the north. Assumed is that only 10% of the domestic transport should be counted twice in the calculation. Domestic transport: 310.200 TEU

Many containers leave the port empty, because much more is imported than is exported. 58% of the total amount of containers will be sent back empty; this is 908.667 TEU.
In this case is assumed that the total domestic flow is balanced; no empty containers appear in this circuit.
Part of the containers will be transported to and from the hinterland by inland waterway. The vessels that take care of this form of transport are much smaller than the container vessels. Therefore extra berths will be designed for these ships in a special inland barges terminal. This will not be taken into account in this calculation. The calculations for this terminal can be found at the end of this section.

Table 3.1: total number of containers in 2020

Import (TEU)	Full containers	1.096.667
Export (TEU)	Full containers	188.000
	Empty containers	908.667
Domestic (TEU)	One way sea-transport	282.000
	Two way sea-transport	28.200
TOTAL		**2.503.534 TEU**

Part of all these TEU will be handled in 40 feet containers (FEU), however this has been taken into account in the above-mentioned formula for production per year per container berth.

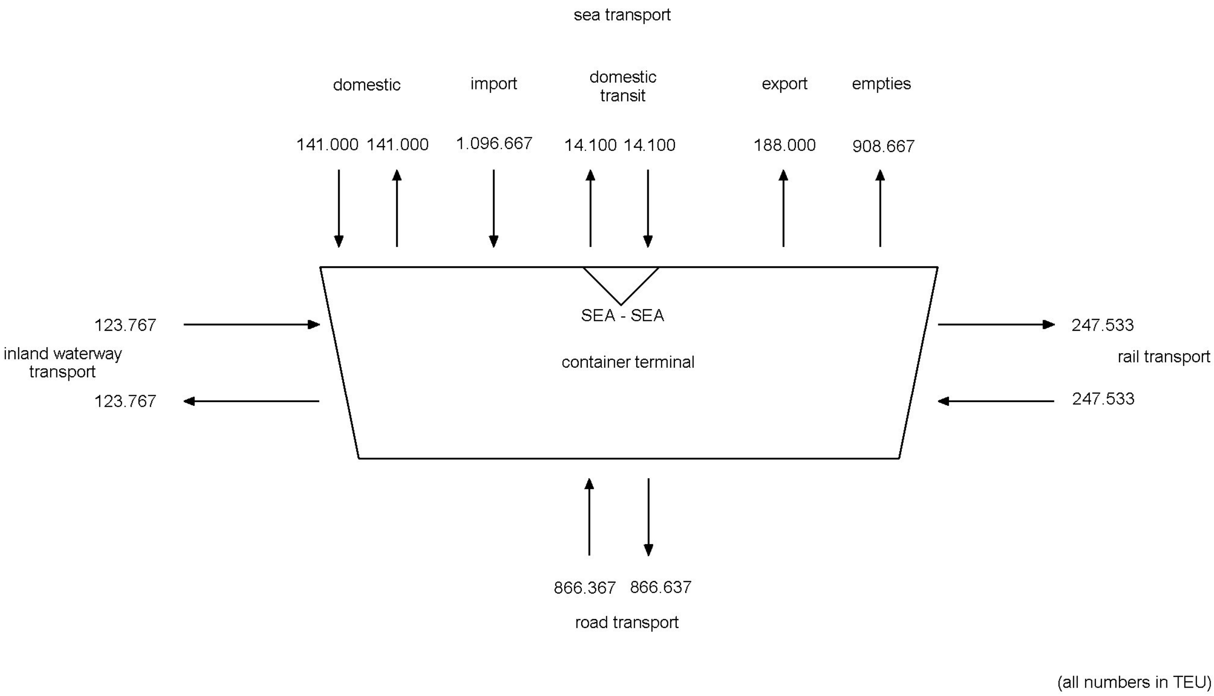

Figure 3.2: modal split container cargo

The total expected amount of containers to be handled for the year 2020 is 2.503.534 TEU. This should be divided by the average number of TEU that is handled by each vessel, suppose X.
So the arrival rate λ is:

$$\lambda = \frac{2.503.534}{X}$$

$$\rho = \frac{\lambda}{\mu}$$

In which:

ρ	=	*utilisation*
λ	=	*arrival rate*
μ	=	*service rate of customers*

$$\rho = \frac{2.503.534/X}{1.073.088/X} = 2.33$$

For container cargo a chance of delay of 10% of the service time is the maximum percentage that is acceptable. Three berths will be assumed firstly.

The utilisation:

$$u = \frac{\rho}{n} = \frac{2.33}{3} = 0.78$$

Use will be made of the $E_2/E_2/n$ queue system. This system best reflects the rather regular arrival and service rates of the container vessels. The arrival and service rates of this system are based on an Erlang probability distribution function.

Table V of '*Service systems in ports and inland waterways'* [9] gives an average waiting time in units of the average service time. For three berths and a utilisation of 0.78, this table gives an average waiting time (*W)* of 0.4135 in units of the average service time. This value exceeds the accepted chance of delay of 10% of the service time ($W_{acc} = 0.10$). The next table shows the results for three and four berths. Four berths amply suffice the acceptable chance of delay ($W < W_{acc}$). Four berths seem a reasonable number to handle the container vessels calling in at Haiphong port.

Table 3.2: container berths 2020

n	3 berths	4 berths
u	0.780	0.583
W	0.4135	0.0620
W_{acc}	0.1000	0.1000

n = *number of berths*
u = *utilisation*
W = *average waiting time of ships in the queue (in units of the average service time)*
W_{acc} = *acceptable chance of delay (in units of the average service time)*

The average service time for a container ship is calculated in the following formula. For the vessel capacity an amount of 4000 TEU is used, this is 2000 TEU unloading and 2000 TEU loading.

$$T_{serv} = \frac{C_v}{p * N * f} = \frac{4000}{22.5 * 4 * 1.38} = 32.2\,hrs$$

T_{serv}	=	*service time*	*[hrs]*
C_v	=	*vessel capacity*	*[TEU]*
p	=	*gross production per crane*	*[moves/hr]*
N_v	=	*number of cranes per berth*	*[-]*
f	=	*TEU factor*	*[-]*

The service time exceeds the international accepted service time of 24 hrs. This is mainly caused by the low crane production per hour. When the port is able to operate with high quality equipment, for example cranes that can move 40 containers per hour, the service time will decrease rapidly. However this type of cranes has not yet been developed. At the moment the most modern types have a gross production of 30 moves per hour. In that case the service time would be around 24 hours.
When referring to the assumed necessary mooring time of 10% of the total service time, it can now be seen that this would be 3.2 hrs (10% of 32.2 hrs). This seems reasonable. Usually at least two hours are counted for berthing. Another hour will be spent on custom formalities etc.

3.2.3 Container berths in 2010

The expected amount of container cargo for 2010 is less, namely 533.333 TEU. This can be taken into account when the executive planning is made. It will not be necessary to construct all four berths at the same time.
Since the im-/export figures are assumed to be the same for 2010 and 2020, the λ will comparatively increase from throughput expectation till the number of TEU to be handled including the empties and double counting domestic traffic.
For 2020 the throughput expectation was 1.566.667 TEU, the numbers of TEU to be handled 2.503.534.
The following calculation has been made to determine the number of berths required in the year 2010.

$$\frac{2.503.534}{1.566.667} = 1.60$$

The expected container throughput for 2010 is 533.333 TEU. This means that 1.6 * 533.333 = 853.333 TEU has to be handled in the new port.

$$\rho = \frac{853.333/X}{1.073.088/X} = 0.795$$

Again a chance of delay of 10% will be assumed. Two berths will be assumed first.

The utilisation:

$$u = \frac{\rho}{n} = \frac{0.795}{2} = 0.398$$

Use will be made of the $E_2/E_2/n$ queue system. Table V of *'Service systems in ports and inland waterways'*[9] gives a waiting time (*W*) of 0.0569, in units of the average service time. This amply answers the requested chance of delay.
One berth though, will not satisfy this demand. (u = 0.795, W_{acc} = 0.1000, W = 1.8240)
By the year 2010 the construction of two berths has to be finished to fulfil the supply.

3.2.4 Inland barges terminal

At the moment only 10% of all transportation to and from the hinterland is done by inland barge. This amount is quite low, because the Vietnamese inland waterways are not in a very good condition. As long as this will not be improved drastically, it is reasonable to assume that the same percentage of transportation can be used for the year 2020.
An inland barge terminal should be designed for the container transport of 10% of all the container cargo to and from the hinterland. Assumed is that these containers will be transported by vessels with a capacity of 100 TEU (design vessel: L 110m, B 11.4m, D 3m). This is rather large for a common inland barge. Since the vessels have to sail at open sea before they are able to enter the port, it is not advisable to use smaller vessels. The Vietnamese inland waterways are not very safe and well maintained yet. This could cause problems for these rather large inland barges. At the moment there are plans to develop and improve the inland waterways. It is recommended to execute these plans in the near future to avoid dangerous situations.

Table 3.3: total amount of container moves per type of transport

Type of transport	Type of container	Containers (TEU)	10% inland barge (TEU)
Import	Full containers	1.096.667	109.667
Export	Full containers	188.000	18.800
	Empty containers	908.667	90.867
Domestic	One way sea-transport	282.000	28.200
	Two way sea-transport	28.200	-
TOTAL		**2.503.534 TEU**	**247.534 TEU**

In the following modal split the cargo flow has been reflected.

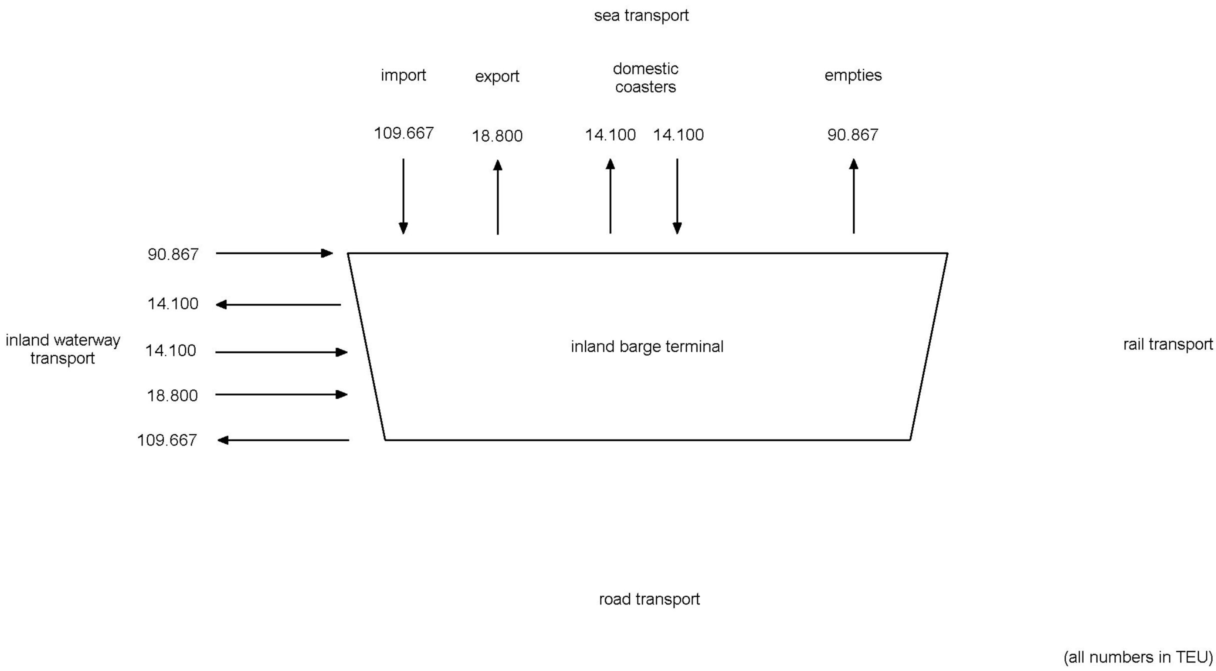

Figure 3.3: modal split inland barge cargo

First the production (in TEU) per year per container berth with maximum capacity will be calculated:

$$\mu = t_n * N_b * p * f$$

For this smaller type of vessel only 2 cranes per vessel are working at the same time.

$$\mu = 24 * 360 * 2 * 22.5 * 1.38 = 536.544\, TEU / yr$$

$$\mu = \frac{536.160\, TEU / yr}{X\ TEU / vessel} = \frac{536.160}{X} vessels / yr$$

The total expected amount of containers to be handled in the inland barge terminal is 247.534 TEU.

$$\lambda = \frac{247.534}{X}$$

$$\rho = \frac{247.534/X}{536.160/X} = 0.461$$

Again a chance of delay of 10% will be assumed. One berth will be assumed first.

The utilisation:

$$u = \frac{\rho}{n} = \frac{0.461}{1} = 0.461$$

Use will be made of the $E_2/E_2/n$ queue system. Table V of *'Service systems in ports and inland waterways'* [9] gives a waiting time (W) of 0.3300, in units of the average service time. This does not answer the requested chance of delay (W_{acc} = 0.1000). Therefore two berths will be calculated (u = 0.231, W_{acc} = 0.1000, W = 0.0118). This number amply suffices the maximum acceptable chance of delay. By the year 2020 the construction of two inland barge berths has to be finished to fulfil the supply of the container vessels.

3.2.5 General cargo

For the general cargo another couple of berths have to be constructed. The production per year per berth (service rate μ) will be different though.

$$\mu = t_n * N_b * p$$

t_n	=	*number of operational hours per year*	*[hrs/y])*
N_b	=	*number of gangs per berth*	*[-]*
p	=	*average gang productivity*	*[tons/hr]*

For this port the following values will be taken:

t_n	=	*24 hrs/day * 360 productive days/year = 8640 hrs/yr*
N_b	=	*4 gangs per berth, (1 gang per hold)*
p	=	*30 tons/hr*

The service time that is necessary to moor the vessels should be taken into account as well. This corresponds with approximately 2% of the time that a vessel is at the quay (suppose a vessel stays at the berth for 6.5 days and 3 hours are spent to berth; this corresponds with 2%). This will decrease the average gang productivity per year per berth. Therefore the average gang productivity will be cut back by 2% and will now be 29.4 tons/hr.

$$\mu = 24 * 360 * 4 * 29.4 = 1.016.064 \ tons/yr$$

μ is the total amount of tons that can be handled per berth per year. The vessels will not unload 100% of their load though. Therefore it is assumed that X tons of every vessel will be handled in the port. It seems reasonable to take a value for X that is around 50% of the total capacity.
μ should be divided by the number of tons that need to be handled of each vessel (X).

$$\mu = \frac{1.016.064 \ tons/yr}{X \ tons/vessel} = \frac{1.016.064}{X} \ vessels/yr$$

Expected amount of general cargo for the year 2020: 1.500.000 tons. In this case no 'empties' have to be taken into account. Just like for the containers, 10% of the domestic cargo will be counted twice, because that part will be transhipped in the port. This is an amount of 27.000 tons. Inland waterway vessels will transport 10% of the total volume of general cargo to the hinterland. These vessels will moor at the same berths as the seagoing vessels. This means that an extra 10% of 1.500.000 tons, which is 150.000 tons will be handled on this quay. The modal split of this situation is given in figure 3.4.

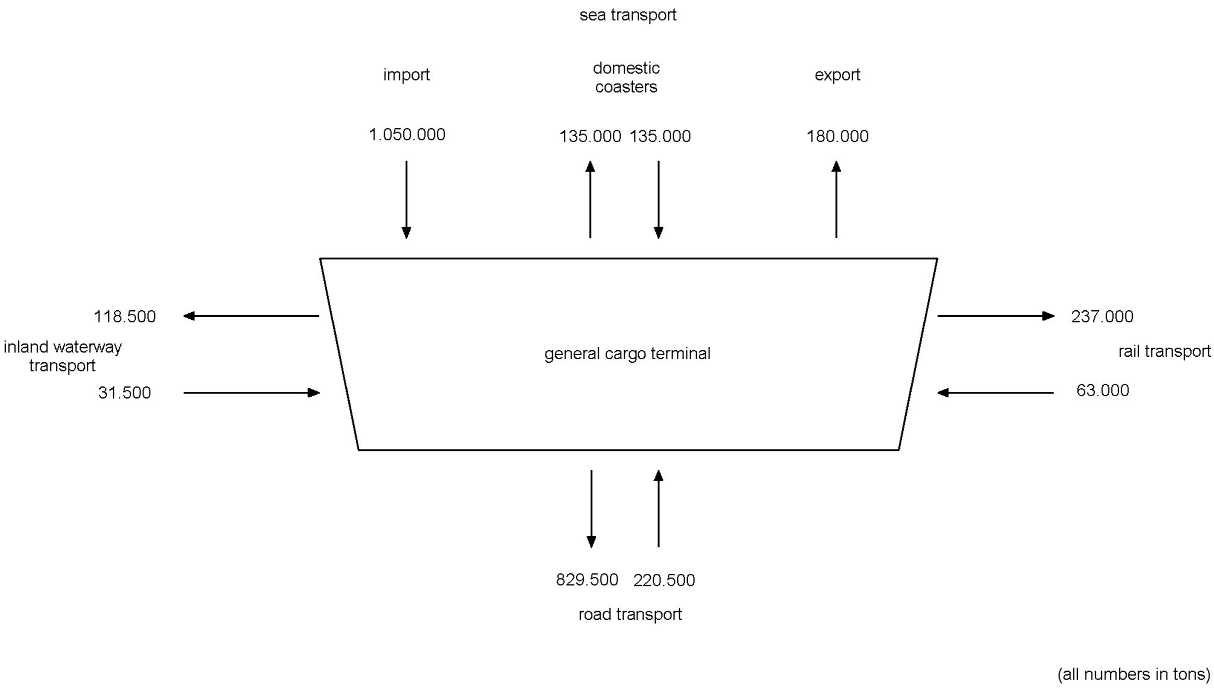

Figure 3.4: modal split general cargo

In total an amount of 1.677.000 tons has to be handled in the new port. This should be divided by the average number of tons that is handled by each vessel, suppose X.
So the arrival rate λ is:

$$\lambda = \frac{1.667.000}{X}$$

$$\rho = \frac{\lambda}{\mu} = \frac{1.667.000/X}{1.016.064/X} = 1.64$$

A chance of delay of 25% of the service time will be taken as acceptable. Firstly three berths will be assumed.

The utilisation:

$$u = \frac{\rho}{n} = \frac{1.64}{3} = 0.547$$

Use will be made of the M/E_2/n queue system. This system fits better for general cargo vessels than the E_2/E_2/n system, because of the more irregular character of the arrival of the vessels. Table IV of '*Service systems in ports and inland waterways'* [9] gives an average waiting time in units of the average service time (*W*) of 0.158. This value satisfies the accepted chance of delay of 25% of the service time (W_{acc} = 0.250). The situation in case of two berths will be considered to check whether it is possible to operate the port with only two berths.

Table 3.4: general cargo berths, 2020, acceptable chance of delay 25%

n	**3 berths**	**2 berths**
u	0.541	0.810
W	0.158	1.604
W_{acc}	0.250	0.250

n = *number of berths*
u = *utilisation*
W = *average waiting time of ships in the queue (in units of the average service time)*
W_{acc} = *acceptable chance of delay (in units of the average service time)*

In the above table it can be seen that four berths amply fulfil the demand; the acceptable chance of delay will not be overstepped.

The average service time for a general cargo ship is calculated in the following formula. It is assumed that the vessels will unload more than that they load (import > export); in the next calculation is assumed that averagely 65% of the vessels load will be unloaded and 25% will be loaded. The total capacity of the average vessel is 20.000 DWT. For the vessel capacity an amount of 18.000 tons is used, this is 13.000 tons unloading and 5.000 tons loading.

$$T_{serv} = \frac{C_v}{p * N} = \frac{18.000}{29.4 * 4} = 153\ hrs = 6.4\ days$$

T_{serv}	=	*service time*	*[hrs]*
C_v	=	*vessel capacity*	*[tons]*
p	=	*average production per gang*	*[tons/hr]*
N	=	*number of gangs per berth*	*[-]*

So summarizing, the following number of berths is required:

- 2 container berths in the year 2010
- 4 container berths in 2020
- 2 inland barge berths in 2020
- 3 general cargo berths in 2020

The reason that the required number of general cargo for 2010 has not been established is that in this year the old port still can handle the expected amount of general cargo. Nevertheless, it will be recommended to start constructing the berths by this time, so that larger general cargo vessels (>10.000 DWT) can also visit Haiphong deep-water port.

3.2.6 Required quay length

$$L_q = 1.1 * n * (L_s + 15) + 15$$

L_q	=	*quay length*	*[m]*
n	=	*number of berths*	*[-]*
L_s	=	*length of the largest vessel frequently calling at the port*	*[m]*

2 container berths in 2010:

$$L_q = 1.1 * 2 * (300 + 15) + 15 = 708\,m$$

4 container berths in 2020

$$L_q = 1.1 * 4 * (300 + 15) + 15 = 1401\,m$$

2 inland barge berths in 2020

$$L_q = 1.1 * 2 * (110 + 15) + 15 = 290\,m$$

3 general cargo berths in 2020

$$L_q = 1.1 * 3 * (186 + 15) + 15 = 678\,m$$

3.3 Water area

Furthermore the first approximate calculations on the access channel and port basin will be done in this section. The exact dimensions of the access channel will depend on the location, but it is possible to calculate the basic dimensions first. They can be used to determine the most favourable port location. Afterwards the dimensions have to be looked at again.

3.3.1 Channel depth

The design container vessel is the vessel with the largest depth. This vessel will be used as the design vessel in this section.

$$d = D - T + s_{\max} + r + m$$

The channel depth can be determined with the following formula:

In which:

d	=	*guaranteed depth (with respect to a specified reference level)*	*[m]*

D	=	*draught design depth*	*[m]*
T	=	*tidal elevation above reference level below which no entrance is allowed*	*[m]*
s_{max}	=	*maximum sinkage (fore or aft) due to squat and trim*	*[m]*
r	=	*vertical motion due to wave response*	*[m]*
m	=	*remaining safety margin or net underkeel clearance*	*[m]*

D	=	*12 m*
T	=	*0, no tidal window will be used*
s_{max}	=	*0.5 m*
r	=	*first estimation = 0.5 H_s = 0.5 * 1.5 = 0.75 m*
m	=	*soft mud, 0.3 m*

$$d = 12 - 0 + 0.5 + 0.75 + 0.3 = 13.55\,m$$

The port authority does not want to limit ships entering the port by using a tidal window. They want ships to be able to enter the port 24 hours per day.
The waves are one factor that does limit the entering of ships. A wave window is necessary, because of the regular typhoons that occur three to four times a year. During these storms the waves can be very high, which makes it hard or impossible for the ships to enter. Accurate wave data will give more insight in the situations when this will occur.

3.3.2 Channel width

The design container vessel will be used in this section; its beam is 40 m. The draught of the vessel will be compared to the water depth. This determines the basic width of the channel. Some additional factors influence the width as well.

d = 1.1 D → basic width W_{BM} = 1.7 B

Additional width W_i:

Prevailing cross-winds 15-33 kn	0.4 B
Prevailing cross-current 0.5-1.5 kn	0.7 B
Prevailing long-currents 1.5-3.0 kn	0.1 B
Prevailing wave-height 0.5-1.0 m	-
Aids to navigation	0.1 B
Seabed characteristics soft	0.1 B
Cargo hazard medium	0.5 B
Total Wi	1.9 B

W_B = Bank clearance sloping edge 0.5 B

Initially is chosen for a one-way channel. In consideration of the number of vessels expected, this seems reasonable. Further investigation by means of a simulation program is required to establish if this assumption is correct. Apart from that, extra attention should be paid to the tidal currents and tidal differences to make sure that vessels will not get stuck in a too narrow channel.
One way channel:

$$W = W_{BM} + \sum W_i + 2W_B$$

$$W = 1.7B + 1.9B + 2 * 0.5B = 4.6B = 184\,m$$

When the vessels enter the port, the breakwaters will protect them from cross-currents and waves. The width that is sufficient within the breakwaters is:
W_i = 1.2 B

$$W = 1.7B + 1.2B + 2 * 0.5B = 3.9B = 156\,m$$

3.3.3 Inner channel and turning basin

Inside the breakwaters a length of 2-3 L_s must be kept free before narrowing the channel. This will give the captain or pilot time to react on the increasing drift angle of the ship, which will arise because the bow of the ship is moving out of the current and the moment on the ship increases. When the vessels enter the more narrow part of the channel the tugboats will tie up and slow down the vessel. At the

end of the inner channel a turning basin is located. From here ships are towed to their respective basins. The turning circle has a diameter of at least 2 L_s.
Maximum L_s design container vessel: 300 m

3.3.4 Port basin

The port basins minimum width is 4 to 5B + 100 for conventional cargo and container ships. B = 40 m, so the basin width should be 260 to 300 m.
It has to be kept in mind that, in case the quays will be build as one long basin (>1000 m), it is desirable that ships can be turned in the basin. The required width is about 8B + 50 = 320 + 50 = 370 m. This would be the case when the whole container quay will be built in one basin.

Another part of the port basin has to be allocated to the tugboats, pilot launches and oarsmen. This part should be well protected, because the smaller vessels are more sensitive to wave distribution. For the pilot and tow services it is practical that the vessels are located rather close to the port entrance. The oarsmen operate close to the quays.

Concerning the berth orientation, it can be said that influences of waves and currents will be strongly limited by breakwaters. For safe berthing, the berth should preferably be aligned within about 30° of the prevailing wind direction (north-east in winter and south-east in summer). For container vessels the limiting operational wave height is 0.5 m (head or stern). A wave penetration model can give more insight in the wave agitation in this port.

3.3.5 Morphological aspects

Morphological aspects will affect the port layout, but the port will have influence on the morphology as well. It is hard to predict these influences in this stage of the study. After the location of the new port has been determined more specific models can be used to research the morphology aspects.

The main morphological problem is the high siltation rate in this area. Maintenance dredging must be done continuously to keep the channel at the right depth. The amount of sediment, transported by the rivers that empty into the Gulf of Tonkin, is enormous. The port has to be located as close as possible to the deeper parts of the Gulf; otherwise the dredging costs will be too high.

The effects of the breakwaters on the natural littoral transport have to be taken into account in the design phase. They might cause accretion or erosion of the adjacent coastlines.

Because so much sediment is present in the water of the Gulf, extra attention should be paid to possible sedimentation inside the port due to tidal filling or density currents. The exchange of sediment filled water in an eddy behind the breakwater could cause problems as well.

3.4 Terminal area

The terminal area will consists of two parts; one part for the container handling and one for the general cargo. In this section the basic dimensions of these two areas will be determined.

3.4.1 Container terminal

The container terminal must be able to handle the following ships in the year 2020:
Design vessel L 270-300 m
B 38-40 m
D 12 m
The ships will moor at 4 berths with a total quay length of 1401 m.

The terminal facilities consist of an apron area and a storage yard. Further facilities like offices, gates, roads and the like will not be worked out in this phase of the study. Assumptions will be made on the required surface for these facilities.

The apron area consists of a service lane, crane track spacing, a place for hatch covers and a traffic lane to transport the containers between storage yard and quay.
The service lane (3-5 m) provides access to the ships for the crew and for supplies and services. In consideration of the crane stability crane track spacing has to be built. This space could be used for

transport equipment as well. Behind the landward rail space must be reserved to place the hatch covers. For the transport between the quay and the storage yard a traffic lane should be constructed.

Service lane	5 m
Rail gauge	35 m
Backreach	15 m
Transport lane	35 m
Apron width	90 m

Assumed that the apron width stretches out over the full quay length, this will be an area of 90 * 1401 = 126.090 m^2

The storage yard is set up in separate stacks for import, export, reefers, hazardous cargo and empties. The following table shows the expected division of the cargo.

Table 3.5: dwell time per type of container

Type of container	Number of containers (TEU)	Max. dwell time (days)	Dwell time (days)
Import	1.096.667	18	7
Export	188.000	15	6
Empties	908.667	25	9
Domestic	282.000	15	6

The assumption is made that 5% of the import containers will arrive as a reefer. This is a number of 54.833 TEU. The remaining number of import containers is 1.041.834 TEU. For hazardous cargo a separate area will be reserved.
A Container Freight Station (CFS) is used for cargo that has to be stripped or stuffed. After an import container is stripped and before an export container is stuffed, the cargo is stored in the CFS, which is covered. The percentages of containers going through this station have been assumed as following:

Table 3.6: number of containers per storage type

Type of container	Total number of containers (TEU)	% through CFS	Number through CFS (TEU)	Number through regular storage (TEU)
Import (- reefers)	1.041.833	35%	383.833	658.000
Reefers	54.833	-	-	54.833
Export	188.000	35%	65.800	122.200
Empties	908.667	-	-	908.667
Domestic	282.000	15%	42.300	239.700

The calculations on the required regular storage areas per type of container can be found in Appendix V.

The surface areas, calculated in Appendix V, required for import, export, domestic, empty and reefer containers are as following:

Import	320.487 m^2
Export	50.591 m^2
Domestic	99.237 m^2
Empty	367.680 m^2
Reefers	28.042 m^2

Total required area for stacking: 866.037 m^2

The calculation of the required surface area for the Container Freight Station can be found in Appendix V as well. The required surface area O_{CFS} for each type of cargo is:

Import	226.127 m^2
Export	32.227 m^2
Domestic	21.360 m^2
Total	**279.714 m^2**

The following ratio is used to check whether the above-calculated surface area (126.090 m^2 + 866.037 m^2 + 279.714 m^2 = 1.271.841 m^2) is in the right order of size. Offices, roads, garages etc. have not been taken into account in this surface area.
Total gross surface area calculated on the basis of the throughput-area ratio of 15.000 TEU/ ha → 2.475.334 / 15.000 = 165 ha = 1.650.000 m^2. In this case offices, roads and garages have been taken into account. Therefore it can be concluded that the order of size is correct.

3.4.2 General cargo terminal

The container terminal must be able to handle the following ships in the year 2020:
Design vessel L 186 m
B 27 m
D 9 m
The ships will moor at 3 berths with a total quay length of 678 m.

For general cargo quays an apron width of 25 m is a minimum, it should preferable be 30 m.

The storage area consists of two different types of storage, namely a transit shed and an open storage. In the following calculations is assumed that 60% of the cargo passes through the transit shed and 40% will be stored in an open storage. A warehouse will not be used at this terminal. The required areas have been calculated in Appendix VI.
Transit shed 42.270 m^2
Open storage 35.225 m^2

For the first rough layout sketches a general cargo storage area of 77.500 m^2 will be assumed. This does not include the extra space that is needed for the delivery zone and the quay-apron width. The delivery zone has a width of 45 m to enable long trucks to move into and out of loading bays along the transit sheds. Assumed that both the apron and the delivery zone are constructed along the full quay length, an extra (30+45) * 678 = 50.850 m^2 is added.

3.4.3 Terminal dimensions

If the above-calculated terminal areas are added, the following is obtained:

Container storage	866.037 m^2
CFS	279.714 m^2
Container apron	126.090 m^2
Total Container area	1.271.841 m^2
General cargo storage	77.495 m^2
General cargo apron + delivery zone	50.850 m^2
Total General Cargo area	128.345 m^2

Internal roads, offices, garages etc. are not included in this calculation. Because both terminals are part of one port, some of these facilities can be shared (f.e. offices).

3.5 Sub-variants Cat Hai

To determine the most suitable location for the new deep-water port, for both variants two simple port layouts will be developed on the basis of above-mentioned dimensions of the water area, terminal facilities and port basin. These sub-variants are not detailed at all. They will make it possible to carry out a Multi Criteria Evaluation though, which will give more insight in the most suitable location. The terminal area on land for example will not be worked out in these layouts. It has just been made sure that there is enough space to build the required number of terminal square meters.
Hereinafter two sub-variants for the Cat Hai Island location will be discussed shortly. In the next section the same will be done for the variant south of Doson. The (dis-) advantages will be discussed more thoroughly in section 3.7, where the evaluation is performed. Maps of all sub-variants can be found in Appendix VII.

3.5.1 Sub-variant 1

The first sub-variant is based on the knowledge that in future the river Lach Huyen and the Trap Canal are going to be used as the main access channel for the old Haiphong port (see map in Appendix VII). From the year 2005 it is scheduled to use this route. The natural depth of the river Lach Huyen is already deeper than the depth of the river Nam Trieu. Maintenance dredging has to be done at the river Lach Huyen to use it as an access channel to the old port. It will be relatively cheap to dredge it a little deeper for the first part and use it as an access channel for the deep port as well. The new port can be situated south of the eastern entrance of the Trap Channel. This piece of land is located rather sheltered, so large breakwaters will not be necessary. There is enough space for the ships in between the islands of Cat Hai and Cat Ba to manoeuvre and turn.

Even though the access channel will be used for two aims, it is still a large part that has to be dredged. Over 20 kilometres of the access channel is not deep enough to reach the port without dredging.

Extension of the port in future is rather easy. The port can be extended southwards. The area south of Cat Hai Island is not deep and landfill can be used to create extra land.

The hinterland connections from Cat Hai Island to Haiphong are, as was mentioned in chapter 2, rather difficult, because several rivers have to be crossed. The shortest way will be to build a bridge from the westside of Cat Hai (just southwards of the Trap Canal) to the eastern end of Dinh Vu peninsula. From there a connection can be build with Highway No. 5 and the railway network. Even though it is the shortest way, it is still a distance over 4 km that has to be bridged. By that time the River Nam Trieu will not be the main access channel to the old port anymore, but still ships will use this channel. The bridge should not bother the traffic on this river too much.

Another option is to transport the cargo over land to the northwest of the island and cross the river Nam Trieu over there to Dinh Vu peninsula. The bridge can be a lot smaller in this case, but an extra part of road of at least 11 kilometres has to be built and the traffic crosses the Trap Canal now. Since the Trap Canal is part of the access channel to the old port, this is not a very attractive option. Both options are drawn in Appendix VII (map 3).

The possibilities for inland waterway transport are good from this location. Via the River Lach Huyen and Trap Canal the vessels can enter the inland waterways of northern Vietnam.

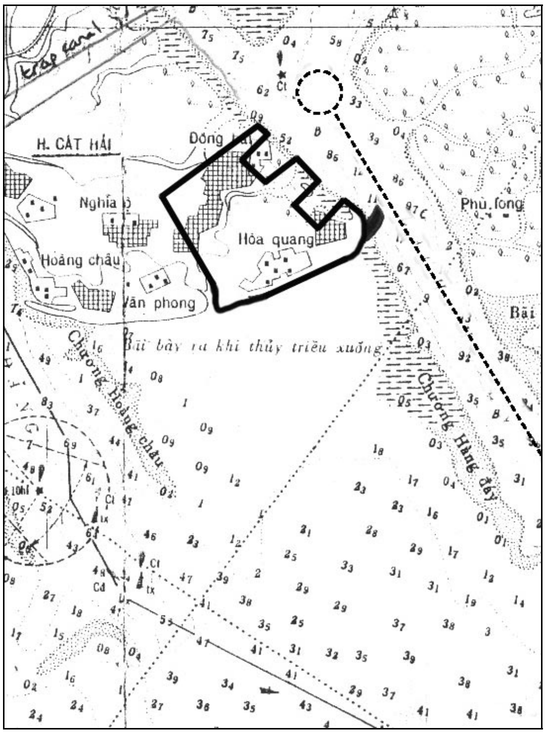

Figure 3.5: first sub-variant Cat Hai

3.5.2 Sub-variant 2

The second sub-variant is located more southwards. In this sub-variant use is made of the very shallow water off the coast of Cat Hai Island. A sand bank is situated west of the access channel to the mouth of Lach Huyen and stretches out from the southeast point of the island in southeast direction over a distance of 8 kilometres. The new port is located at the end of this sand bank. It will be necessary to use landfill to build a road and the required land for port facilities. The dredging costs on the other hand will be much lower. The access channel to reach the port will be 8 km only. Because the surrounding islands do not protect this location, breakwaters have to be constructed to protect the port basin from waves and currents.

The extension possibilities for this port are several, both in seaward direction as northwards. At the north-eastern side of the road quays can be built in future as well.
The hinterland connections are the same as they are for the first variant. The cargo only has to be transported an extra 8 km over the sand bank.
The layout is shown in figure 3.6, a more extensive map can be found in Appendix VII.

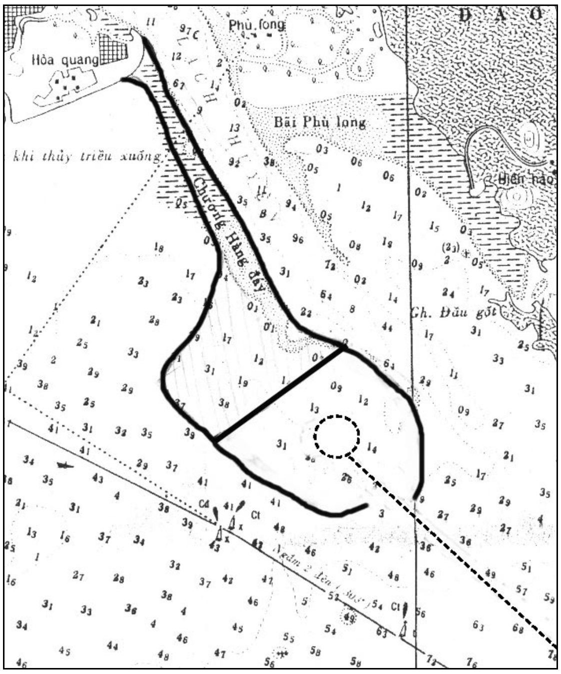

Figure 3.6: second sub-variant Cat Hai

3.6 Sub-variants south of Doson

The area south of Doson is very shallow. The distance from the land to an area with a depth of 13 m is at least 15 km. The first 5 km exist of sand banks and water with a depth of 0 to 3.5 m. The optimum between landfill and dredging has to be found. The two sub-variants vary in this aspect.

3.6.1 Sub-variant 1

In this sub-variant is chosen for a rather large amount of landfill. This land can be used for storage and other port facilities, as well as for industrial activities. It is also possible to extend the port westwards in future. The distance to deep water is approximately 9 km.
To preserve the peninsula and the people who live there, the layout is designed in a way that the water is still surrounding Doson. This does make it necessary to build an extra breakwater/ dike, to create the separation. In a later stadium it can be studied if this is desirable or not.
Because the entrance of the port is at the southeast side the influence of the River Van Uc will be small. A morphology study has to be carried out, but it is not expected that the sediment transported by the river will be of any harm for the port entrance.
The hinterland connections in this area are not yet developed, but it is rather easy and not too far to construct a connection to the recently rebuild road from Doson to Haiphong. There is no railway network in this area. A new track could be built along the road to Haiphong and will be approximately 22 km. From Haiphong the port is connected to the Vietnam railway network and Highway no. 5. For the inland waterway transport it will be rather difficult to reach Haiphong. The nearby River Van Uc does not make any connection with Haiphong and its hinterland. The vessels have to go back seawards and enter the River Nam Trieu to reach Haiphong since the Dinh Vu dam closes of the River Cam. For some of the inland waterway vessels this might be difficult, because the waves can be rather high in this area.
The basic layout is shown in figure 3.7. A more extensive map can be found in Appendix VII.

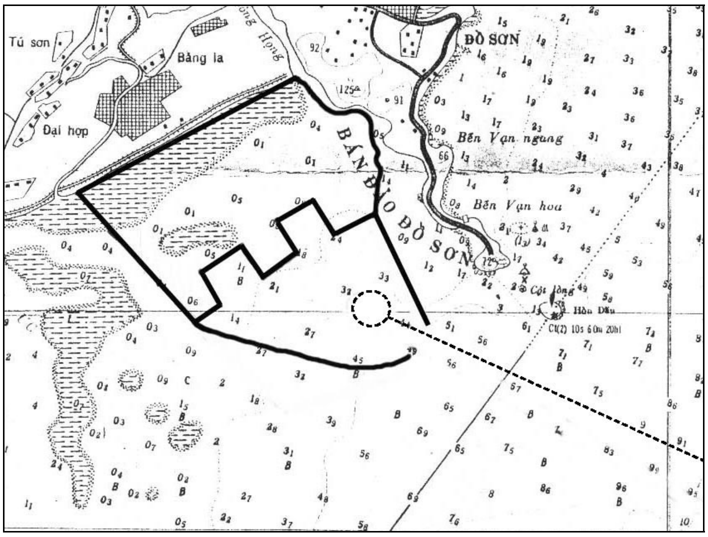

Figure 3.7: first sub-variant southwards of Doson peninsula

3.6.2 Sub-variant 2

In the second sub-variant hardly any land has to be filled. The port will be built closer to the shore. This will save a lot of money, but the dredging costs on the other hand will increase. The access channel will be longer. Furthermore there is a chance that there will be more influence of the River Van Uc and its sediment, although this has not been proven and needs to be studied more thoroughly.
A large breakwater has to be built to protect the port from waves and currents. Because of this breakwater it will be hard to extend the port without having to construct the breakwater all over again.
The Doson peninsula will stay intact with this layout. Even most of the fishermen, living in the corner north-west of the peninsula can stay where they are.
The hinterland connections are the same as in the first sub-variant.

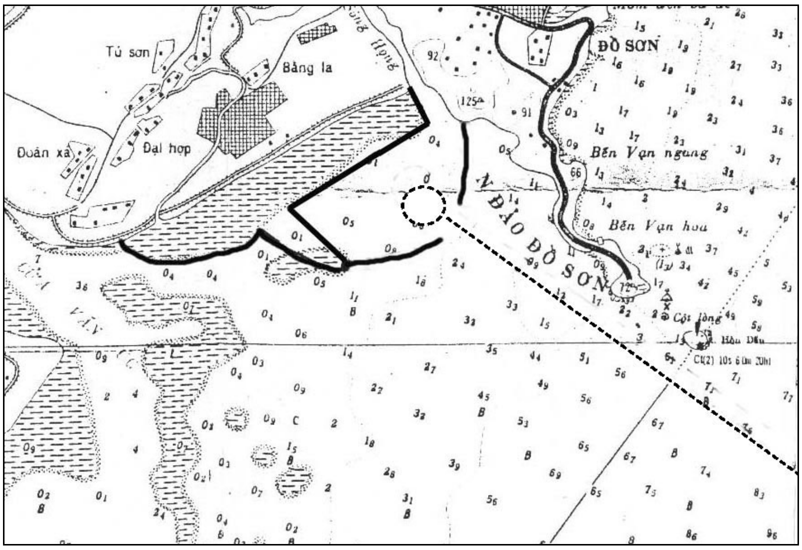

Figure 3.8: second sub-variant southwards of Doson peninsula

For a more extensive map, see Appendix VII.

3.7 Multi Criteria Evaluation[16]

The main goal for this chapter is to choose the most suitable location for the new port. The above outlined sub-variants will be worked out in more detail in the next chapter. The layout of the terminal and storage facilities will be designed in the next chapter as well.
A Multi Criteria Evaluation will be carried out now to choose the most suitable variant. First the main criteria will be determined and shortly described. The costs will be looked at separately.

3.7.1 Qualitative properties

It is hard to decide whether the different variants will function well as far as the land layout, terminal- and storage facilities are concerned. This is, because those parts of the layout are not yet designed. It is possible though to overlook other items of both variants. In this phase of the design the following qualitative properties are important:

- **Functionality**
  - Accessible
  - Reachable (port, access channel)
  - Reachable (hinterland connections)
  - Extendible

The properties mentioned above cover mostly nautical functionality. Accessibility for example, depends on nautical safety and manoeuvrability in the port basin. To what extend the port is reachable depends among other things on downtime.
Good hinterland connections are one of the main pillars to determine if the port functions well or not. The hinterland connections play an important part to what degree the port is connected to its customers. The accessibility of the road and rail connection, the length and the period of time that is required to reach Haiphong all play a part in the property "reachable".
Finally the extendibility of the port is an important factor. It is hard to give an accurate throughput expectation for the next decades. So much can happen and change in 20 years that the port layout and its options have to be very flexible.

- **Construction**
  - Construction in phases
  - Reachable

Phasing of the project is an important factor. The calculated capacity should be reached in 2020. Until then it is possible to construct the port in phases. In that case the first berths could be operational in 2010. This is necessary to relieve the existing port of Haiphong.
It is important that it is easy to reach the port for the construction workers and for the transporters of material. The logistics of the materials should be well organised to save time. Therefore hinterland connections during construction should be efficient, both on the land side and in the water.

- **Environment**
  - Quiet (minor nuisance)
  - Employability
  - Economic space-using

Per (sub-)variant will be overlooked what the influences on the environment are. Hereby it is important that the (sub-)variant causes as little nuisance as possible. Furthermore the space-using should be looked at. How does this bother the environment? Is migration required for the villagers or fishermen? It might also be possible that the (sub-)variant positively influences the environment by for example creating extra employment.

- **Experience**
  - Prestigious

The Vietnamese government would like to build a port that has an international main port charisma. They would like to compete with the main ports of Hong Kong and Singapore. Therefore it is important that the design of the port has a certain prestigious charisma. Of course this mainly depends on the design and capacity of the port, but it could also be possible that the location influences this property.

- **Sustainability**
  - Minor maintenance

Maintenance is a separate factor in this section. It involves both costs and qualitative properties. The costs will be overlooked in another section. When there is a lot of maintenance this will not only costs much, but it bothers the functioning of the port (f.e. downtime) as well.
The parts that bring on minor or more maintenance are dredging works (port basin and access channel) and the breakwaters. These both differ for the different locations. Of course there is much more maintenance, but this depends per layout and will be overlooked in a later stage of the design.

3.7.2 Evaluation

In this section the different (sub-)variants will be evaluated on the above-mentioned properties. A scale factor will be used to take into account the different degrees of importance. The two locations will be judged, if possible per sub-variant.
For the calculations on dredging a depth of 13.55 m is determined and for the width 184 m (one-way channel). The required landfill is calculated to a level of 0 m CD. This is too low; further investigation is necessary to determine the exact height. The mutual proportions are clear though.
For the hinterland connections of the Cat Hai sub-variants only one option will be looked at. This is the option of a longer road and a bridge crossing the river Nam Trieu to Dinh Vu peninsula at the shortest point (in section 3.5.1 this option is explained in more detail).

In the next table a score will be given per qualitative property for each sub-variant. A mark will be given on a scale of 1-10 (10 is best) for each (sub-)criterion.
Afterwards the weights of each property will be determined.

Table 3.7: scores per sub-variant

Main criterion	**Sub-criterion**	**Cat Hai**		**Southwards of Doson**	
		Sub-var. 1	Sub-var. 2	Sub-var. 1	Sub-var. 2
Functionality					
	Accessible	3	7	7	9
	Reachable (port)	5	3	7	7
	Reachable (hinter-land connections)	3	1	9	9
	Extendible	5	3	9	7
Construction					
	Construction in phases	7	1	5	7
	Reachable (site)	3	1	7	9
Environment					
	Quiet (minor nuisance)	1	9	7	5
	Employability	5	7	7	5
	Space-using	1	9	7	9
Experience					
	Prestigious	7	9	7	5
Sustainability					
	Minor maintenance	5	3	7	9

To determine the mutual weight of each criterion the matrix below has been drawn up. A 1 is given when the criterion in the most left column is more important than the criterion in the upper row, a 0 when it is the other way around. In the most right column the scores have been summed up.
The government wants the new port to be a prestigious port, which is well known all over the world and which can compete with other main ports. Furthermore they will support to create extra employment and to use the space in the most optimal way so that as less people as possible have to move out of the area.

Table 3.8: mutual weights

		A	B	C	D	E	F	G	H	I	J	K	Σ
Functionality													
Accessible	**A**		0	0	0	0	0	0	0	0	0	0	**0**
Reachable (port)	**B**	1		0	0	0	1	0	0	0	0	0	**2**
Reachable (hinterland connections)	**C**	1	1		1	0	1	1	0	0	0	1	**6**
Extendible	**D**	1	0	0		0	1	1	0	1	0	1	**5**
Construction													
Construction in phases	**E**	1	1	1	1		1	1	1	1	1	1	**10**
Reachable (site)	**F**	1	0	0	0	0		0	0	0	0	0	**1**
Environment													
Quiet (minor nuisance)	**G**	1	1	0	0	0	1		0	0	0	0	**3**
Employability	**H**	1	1	1	1	0	1	1		1	1	1	**9**
Space-using	**I**	1	1	1	1	0	1	1	0		1	1	**8**
Environment													
Prestigious	**J**	1	1	1	1	0	1	1	0	0		1	**7**
Sustainability													
Minor maintenance	**K**	1	1	0	0	0	1	1	0	0	0		**4**

From the above table it can be seen that the property “accessible” does not score at all. It will get a weight though; otherwise the marks for this property given in table 3.7 will be omitted. In the next table the scores have been multiplied by two, the property “accessible” has got a score 1.

Table 3.9: weighting factor

		Score Σ	Weighting factor
	Functionality		
A	Accessible	1	9
B	Reachable (port)	4	36
C	Reachable (hinterland connection)	12	108
D	Extendible	10	90
	Construction		
E	Construction in phases	20	180
F	Reachable (site)	2	18
	Environment		
G	Quiet (minor nuisance)	6	54
H	Employability	18	162
I	Space-using	16	144
	Experience		
J	Prestigious	14	127
	Sustainability		
K	Minor maintenance	8	72
		Σ=111	1000

Now the scores given in table 3.7 will be multiplied by the weights determined in the above table.

Table 3.10: final scores

Main criterion	Sub-criterion	WF	Cat Hai		Southwards of Doson	
			Score * WF		Score * WF	
			Sub-var. 1	Sub-var. 2	Sub-var. 1	Sub-var. 2
Functionality						
	Accessible	9	27	63	63	81
	Reachable (port)	36	180	108	252	252
	Reachable (hinterland conn.)	108	324	108	972	972
	Extendible	90	450	270	810	630
Construction						
	Construction in phases	180	1260	180	900	1260
	Reachable (site)	18	54	18	126	162
Environment						
	Quiet (minor nuisance)	54	54	486	378	270
	Employability	162	810	1134	1134	810
	Space-using	144	144	1296	1008	1296
Experience						
	Prestigious	127	889	1143	889	635
Sustainability						
	Minor maintenance	72	360	216	504	648
TOTAL		**1000**	**4552**	**5022**	**7036**	**7016**

The results of this evaluation show that sub-variant 1 at the Doson location scores best. The results of the two sub-variants for the Doson location are nearly the same though, and so are the scores of both Cat Hai sub-variants. This is logical, since the location has a big influence on the score for each property. The layouts of the sub-variants can be optimised in a later stage.

3.7.3 Cost estimates

Obviously, costs play an important role in a feasibility study. They are one of the main factors that make a project succeed or fail. In this stage the costs will not be determined in detail; use will be made of parameters. For the different variants the main (and often most expensive) parts will be compared. These are the construction costs of landfill and dredging, breakwaters and the hinterland connections.
Costs for the storage and terminal facilities are not taken into account at this moment. They will be about the same for both locations.
In table 3.11, some quantitative values of certain factors will be summarized. This will help to determine the costs afterwards. Table 3.12 shows the unit prices. The costs per sub-variant have been calculated in Table 3.13.

Table 3.11: quantitative values

	Cat Hai		Southwards of Doson	
Factor	Sub-var. 1	Sub-var. 2	Sub-var. 1	Sub-var. 2
m^3 of dredging (access channel)	28.4 mln m^3	12.2 mln m^3	9.0 mln m^3	17.3 mln m^3
m^3 landfill	-	9.9 mln m^3	3.9 mln m^3	0.05 mln m^3
Km^1 breakwaters	0.5 km	6.5 km	4 km	2 km
Tonnage breakwaters*	205.295 tons	681.876 tons	393.446 tons	133.192 tons
Km^1 rail	15 km 2 bridges of 0.5 km and 1.2 km	23 km 2 bridges of 0.5 km and 1.2 km	17 km	17 km
Km^1 road	15 km 2 bridges of 0.5 and 1.2 km	23 km 2 bridges of 0.5 and 1.2 km	3 km	3 km

*) The calculation on the necessary tonnages per breakwater can be found in Appendix X.[27]

Table 3.12: unit prices

Dredging	$ 1,5 /m^3
Landfill	$ 2,5 /m^3
Breakwaters	$ 16 / ton
Rail	$ 17 mln / km^1 double track
Road (5 cm thick)	$ 15 / m^2
Bridge	$ 1.500 / m^2

Table 3.13: cost estimation per sub-variant

Cost estimation	**in mln $**	**Cat Hai**		**Southwards of Doson**	
		Sub-var. 1	Sub-var. 2	Sub-var. 1	Sub-var. 2
Construction					
	Dredging	42.6	18.3	13.5	26.0
	Landfill	-	24.8	9.8	0.1
	Breakwaters	3.3	10.9	6.3	2.1
	Rail	314.5	450.5	289	289
	Road	24.9	26.5	0.6	0.6
Maintenance					
	Dredging	6.5	3.4	1.7	2.5
	Breakwaters	p.m.	p.m.	p.m.	p.m.
TOTAL		**391.8**	**534.4**	**320.9**	**320.3**

3.7.4 Value/ costs ratio

The following table shows the values, costs and value/costs ratios for the different (sub-) variants. As could be expected the value/cost ratio for both Doson sub-variants is considerably better than the ones for the Cat Hai sub-variants. This is logical since both scores for values and for costs were better than the Cat Hai variant. It is striking to see that the value/ costs ratio for both Doson sub-variants are exactly the same.

Table 3.14: value/costs ratio

Scores	**Cat Hai**		**Southwards of Doson**	
	Sub-var. 1	**Sub-var. 2**	**Sub-var. 1**	**Sub-var. 2**
Values	4552	5022	**7036**	7016
Costs	391.8	534.4	320.9	**320.3**
Value/costs	11.6	9.4	**21.9**	**21.9**

Table 3.15: ranking

Ranking	**Sub-var. 1**	**Sub-var. 2**	**Sub-var. 1**	**Sub-var. 2**
Values	4	3	**1**	2
Costs	3	4	2	**1**
Value/costs	3	4	**1**	**1**

3.7.5 Sensitivity analysis

For this sensitivity analysis two other sets of weighting factors have been determined to check whether the above evaluation has not been influenced by the subjectivity of the chosen weights.
In one set the weights are the same for each property (W_{eq}). The other set is determined from the port authority's point of view (W_{pa}). The port authority's first and most important interest is the nautical safety of the port. Furthermore they attach significance to the construction of the port in phases. In that way parts of the port will be operational as soon as possible.
The results of the different weighting sets are shown in the next table. The exact weights and scores tables can be found in Appendix VIII.

Table 3.16: results different weighting sets

		Cat Hai		Southwards of Doson	
	Results	**Sub-var. 1**	**Sub-var. 2**	**Sub-var. 3**	**Sub-var. 4**
Weights section 3.7.2	**W**	4552	5022	7036	7016
	Value/ costs ratio	11.6	9.4	21.9	21.9
	Ranking	**3**	**4**	**1**	**1**
Equal weights	$\mathbf{W_{eq}}$	4095	4823	7189	7371
	Value/ costs ratio	10.5	9.0	22.4	23.0
	Ranking	**3**	**4**	**2**	**1**
Weights port authority's point of view	$\mathbf{W_{pa}}$	4683	4143	7295	7779
	Value/ costs ratio	12.0	7.8	22.7	24.3
	Ranking	**3**	**4**	**2**	**1**

As can be seen these changes in weights do not have a major influence on the different results. This has been visualised in figure 3.9.
The ranking of the different variants is the same for every set of weights. The value of the Doson variant is higher than the Cat Hai variant in all cases. The ranking of the sub-variants does differ per set of weights although the differences are very small. Therefore more extensive research should be done to the most suitable design for the port.

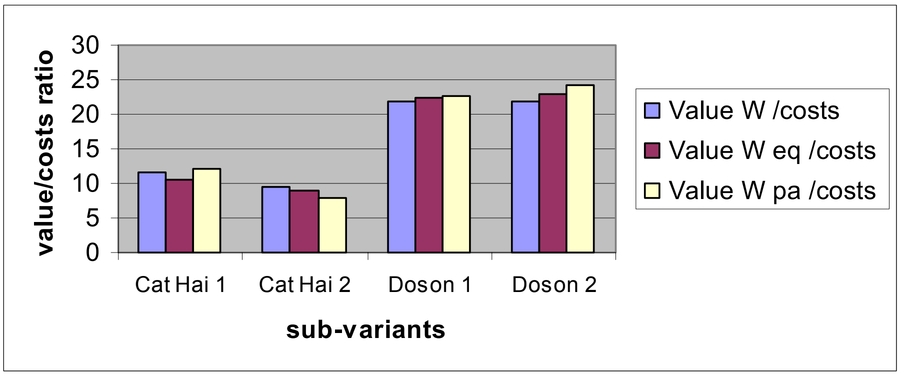

Figure 3.9: value/ costs ratios different weighting sets

In the next chapter further research will be done to the different layout options for the location south of Doson peninsula.

4 Port layout

4.1 Introduction

In this chapter the layout of the port will be developed in more detail. The port will be located south of the Doson peninsula as can be read in chapter 3. In this area of 36 square km (land and water area), many options are possible. Several sub-variants will be developed on the basis of a list of requirements and desires of the Vietnamese government. In the next chapter these sub-variants will be evaluated by means of a Multi Criteria Evaluation. The terminal layout and the bar chart of the executive planning of the final sub-variant can be found chapter 7.

4.2 Required facilities for this port

This section mainly serves to list all the required facilities and equipment of this port, both at the landside and in the water. The compulsory and desired units will be collected here. In the layouts none of these facilities may be lacking. Exact numbers and dimensions will not be mentioned here, those can be find in the list of requirements (section 4.5); this section only serves to deliberate about the necessity and desirability of the separate facilities.

4.2.1 Wet infrastructure

In the water area the two main design points are the access channel and the breakwaters. Both will be discussed more thoroughly in the next section. When the ships enter the port basin they will find several facilities there. Container vessels and general cargo vessels both berth at their own quays. A separate inland barge terminal will be built to serve the barges transporting containers to and from the hinterland. The pilots and tugboats need a separate area, preferably close to the port entrance. It is important that this area is well protected, because of the relatively small size of the vessels.

4.2.2 From quay to storage yard

The space that is required for a safe apron area is discussed in section 3.4.
Ship-to-shore gantry cranes will be used for loading and unloading of the containers. For the transport from quay to storage yard it is advised to use a Multi Trailer System. This system provides a high throughput capacity and can easily absorb traffic peaks. Within the stack use will be made of more dedicated cranes, f.e. the Rubber Tyred Gantry (RTG) or Rail Mounted Gantry (RMG). Further research on the soil conditions should be done before it can be decided which one to use. The soil conditions need to be good to use RTG, otherwise the RMG would be a better choice.
The general cargo vessels will be (un)loaded by the ship's derricks. Per berth two mobile cranes on pneumatic tires will be needed to lift the heavy items. Forklift trucks (FLT) take care of the transport from quay to transit shed. At the quay 3 FLT's will be needed per gang; this means that there should be 4 * 3 = 12 FLT's per berth available. Tractors and trailers supply the transport over longer distances (> 100m), for example to the open storage area. Some extra FLT's and 2 mobile cranes will be required inside the storage.

4.2.3 From storage yard to hinterland

Straddle Carriers are suitable for the transport of containers from the stack to the truck station, because these can move over the truck. There are various types of transport that can be used to move the containers to the railway- and inland barge terminals.
For general cargo, trucks are allowed inside the storage area, in contrast to trains. The railway station can preferably be constructed at the back of the terminal. The inland barges can be handled at the quays for seagoing vessels.

4.2.4 Gate

At the gate all entry and departure procedures will be put through. Customs are located here. All cargo will be registered and the authorities take care of the good handling. In the layouts extra space for offices and garages should be reserved.

4.3 Water area

In the first subsection not only the access channel will be discussed, but also the turning circle and port basin at the end of the channel. First the dimensions will be determined, after that the most favourable position in relation to the waves and wind will be looked at. The calculations on the port basin and turning circle can be found thereafter. The breakwaters will be talked over separately in the next subsection.

4.3.1 Access channel

Dimensions

The following basic dimensions have been determined in chapter 3:

- Channel depth 13.55 m (no tidal window was used, the waves during typhoons will be too high so a wave window should be used)
- Channel width 184 m (one way)

The channel width has now been determined for a one-way channel. The width of a two-way channel would be 376 m (9.4 * B). A simulation of both situations will give a clear view whether a one-way channel could be used or that the acceptable chance of delay of the vessels would be exceeded in that case. For the moment it will be assumed that a one-way channel suffices the posed acceptable chance of delay as is mentioned in section 3.2.

The length depends on the port layout and to what extent the port will be built at the existing land. The further the port will be built in the sea, the shorter the access channel will be. The landfill/dredging ratio will be an important economic factor in the Multi Criteria Evaluation.

Location in relation to wind and waves

The vessels can enter the port in all directions between southwest and southeast in theory. However, it is preferable to position the access channel in such a way that there is a small angle between the dominant wave direction and the axis of the approach channel.

As was concluded in section 2.8, in this case there are two main wave directions, namely NE/E and S/SW. It has to be said that the average wave height in this area is rather low because of the sheltered location of the port.

The shortest connection from port basin to deep water lies in the southeast direction. One should deliberate from an economical point of view which option is the best, taking into account dredging volumes, breakwater length and all-year-round wave disturbance.

The Doson peninsula forms a natural breakwater for waves from the northeast. The same peninsula does not make it possible to position the access channel in a way that it makes a small angle with the NE direction. Nevertheless, from this direction it is not plausible to expect large problems for the vessels. The small islands of Halong Bay prevent the waves from developing a height like they could at open sea.

When the access channel will be situated with a small angle to the south-westerly direction, the vessels have to sail a much longer part through shallow water. This means a large amount of extra dredging work. Because the port will be situated at the coastline, waves from the southwest cannot be very high. Along the coast the water is very shallow. The waves from the south on the other hand loom from open sea and deep water. These waves can cause problems for the vessels. Therefore it seems the best option to position the access channel on the south-north axis in such a way that it makes a small angle eastward.

This direction for the access channel is also the most favourable when the influence of the currents is reckoned with. Although the currents are not very strong (section 2.9.2), they do appear and flow from south to north mainly. Therefore, by choosing this position for the access channel the nuisance that can be caused by cross currents is limited as much as possible.

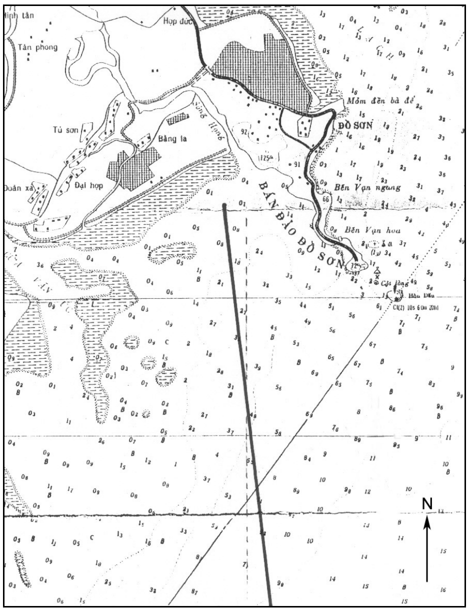

Figure 4.1: positioning access channel

Port basin [turning circle, stopping length]
Before the ships arrive in the port basin they have to slow down. Therefore the stopping length of the vessels should be determined first.

Assume: speed during tying up the tugboats: 4 knots ≈ 2.06 m/s
Time required tying up the tugboats: 10 minutes → 10 * 60 * 2.06 = 1235 m
Stopping distance from 4 kn to 0 kn: 1.5 L_s → 1.5 * 300 = 450 m
Total stopping length is 1235 + 450 = 1685 m

The maximum wave height for tugboats tying up is 1.5 m. The percentage of time that the waves outside the breakwaters will be > 1.5 m is too high to accept as downtime. Therefore the part of the channel inside the breakwaters should at least be 1685 m before the vessels arrive at the turning circle. Immediately behind the breakwaters additional space is required to provide the captain or pilot time to react on the increasing drift angle of the ship. A length of 2 L_s must be kept free before narrowing the channel. Altogether the channel will have a length of 600 + 1685 = 2285 m.
The diameter of the turning circle at the end of the channel should be at least 2 L_s; that is 600 m.

The dimensions of the port basin have been calculated in chapter 3 and will be briefly summarized:
Minimum width: 4 to 5B + 100 = 260 to 300 m
If quays >1000m, then: 8B + 50 = 370 m (ships can be turned in the basin in this case)

Besides the quays, the following facilities should be constructed in such a way that they border the port basin:

- Quay for tugboats and pilot boats
- Quay for inland waterway vessels

This should be taken into account during the design of the different layouts.

Recommendations
For every variant the access channel will be drawn in the map, taking into account the above mentioned dimensions and conditions for the positioning.
The following recommendations are applicable to all variants.

- Although the port authority has emphatically said that they do not want to use a tidal window, it is recommended to further investigate this option. Because of the large amount of dredging even a little tidal window of 0.5 m will save an enormous sum of money. Simulation can be used to find out to what extent this will have influence on the waiting times of the vessels.
- A wave window has to be taken into account. In summer time during the typhoon season, high waves may appear. It is impossible to dimension the channel on these waves. By using a

simulation model it should be determined what a reasonable window would be. More accurate wave data of the area should be available before one can use the model.

4.3.2 Breakwaters

Depending on the port layout the breakwaters should be positioned in such way, that the maximum wave height inside the breakwaters cannot exceed a height of 1.5 m. Furthermore they should hamper the entering vessels as less as possible. Therefore it is important to create extra space right behind the breakwaters.

The main wave direction is from south to north. Therefore it is assumed that there is only littoral transport from south to north, caused by sand from the River Van Uc. This implies that one breakwater would be sufficient.
On the other hand part of the year waves from the east and northeast will appear. The waves will be < 1.5 m most of the time, but in spite of this, the down time (when waves are >1.5 m) will be too large. Therefore a second breakwater will be necessary. A wave penetration model can be used to give more insight in the exact wave agitation in the port as well as in the channel.

4.4 Land area

The required terminal areas and their accompanying surfaces, the stacks, storage yards, transport lanes and offices were calculated in chapter 3, irrespective of the final location, which was chosen afterwards. Exact dimensions can be found in that chapter.
The hinterland connections however were not specified by that time yet, because they do depend on the location. Therefore they will be worked out in further detail in this section.

4.4.1 Hinterland connections

The transport of cargo to and from the hinterland will be done by three means of transportation, namely trucks, trains and inland barges. The present facilities, the necessary extensions and the connection between both will be presented in this section.
<u>Road</u>
At the moment there is a good road connection from Doson to Haiphong. From there trucks can take Highway no. 5 to Hanoi and further. The first and most important thing is thus to create a connection to the Doson-Haiphong road. In future when the traffic flow increases tremendously it might be necessary to broad this road. When the final layout is chosen at the end of this chapter it will be rather easy to design the connection from the truck station at the terminal to the road Doson-Haiphong.

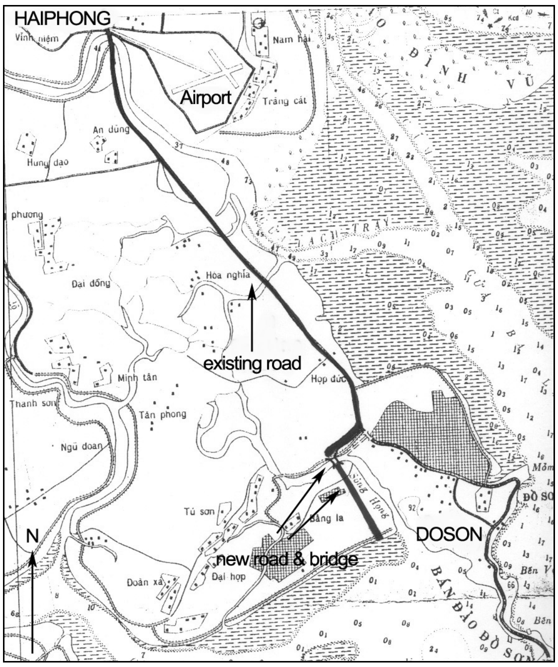

Figure 4.2: road connection to Haiphong

Railway station
There is no rail connection to Haiphong railway station or the existing railway Haiphong-Hanoi. Therefore a complete new track should be designed. Because it is desirable to have the possibility of unloading containers in Haiphong, a station should be build here. The existing station is situated in the town centre. It is advisable to build an extra station outside town, preferable near the existing Haiphong port. Containers can be rearranged here. For the track from the port to Haiphong it seems the best option to follow the road. Figure 4.2 shows this track. One relatively small bridge has to be built.

Inland waterway transport
The general cargo will be loaded and unloaded at the general cargo quays. The inland barges that transport containers use their own terminal. From the port the ships have several options to sail to the hinterland. The most common option is to sail overseas to Haiphong, partly to tranship the cargo in the existing port of Haiphong, partly to pass Haiphong and navigate on one of the main rivers.
Another option for some vessels will be to take the River Van Uc up to Hai Duong (largest city between Hanoi and Haiphong).
In both cases the ships first enter the open sea, when they leave the port. Because these ships are much smaller than the container vessels where the access channel and break waters has been dimensioned on, extra safety measures should be taken.

4.5 List of requirements

In this section all requirements will be summarized and, if necessary, more specified in comparison to chapter 3.

Wet infrastructure

- Access channel
  - Length: depends on the exact location of the port
  - Width: one-way 184 m; two-way 376 m
  - Depth: 13.55 m
  - Position: S-SE
- Inner channel
  - Length: Inner channel, 600 m after breakwaters before narrowing the channel, 1685 m stopping length after narrowing, before turning circle
  - Width: 156 m
  - Depth: 13.55 m
- Turning circle 600 m ∅
- Quays
  - 4 container berths 1401 m
  - 3 general cargo berths 678 m
  - 2 inland barge berths 290 m
  - Pilots, oarsmen and tow services
- Maximum wave height inside breakwaters < 1.5 m

Dry infrastructure

- Mooring equipment
- Apron area width
  - Container 90 m
  - General cargo 30 m
- Storage for containers

Export	50.591 m^2	3-high
Import	320.487 m^2	3-high
Empties	367.680 m^2	5-high
Domestic	99.237 m^2	3-high
Reefers	28.042 m^2	3-high
Total	866.037 m^2	

- Container Freight Station

Export	32.227 m^2
Import	226.127 m^2

Domestic	21.360 m^2
Total	279.714 m^2

- Storage general cargo
  - Transit shed 900.000 tons/yr required area 42.270 m^2
  - Open storage 600.000 tons/yr required area 35.225 m^2
- Separate area for hazardous cargo
- Equipment
- Hinterland
  - Railway station
  - Truck station
  - Roads
- Offices and custom services
- Gate

Utilities
Power supply is not available, so a power plant should be built near the port.
Fresh water supply is not available, so water supply facilities have to be built.

Natural conditions
The dominant wave direction is southeast and the significant wave height is 0.5-1.5 m as an operational condition. The wave period is 6 s.
Prevailing wind directions are NE and S with an average wind speed equal to 3.5 Beaufort.
Tide is diurnal. Tidal difference is about 2.5-3 m. Currents may not complicate the manoeuvring and berthing of the ships.
The bottom mainly exists of mud; the first layer on which quays possibly can be founded is at a depth of 30-40 m.

Hinterland connections
Safe and fast connections to Haiphong are required per rail and road. On the basis of more detailed wave data the most safe inland waterway connection to Haiphong has to be determined.

Life time
The expected lifetime for the project is 50 years.
For economic calculations a period of 30 years is sufficient.

Desires
It is the desire of the Vietnamese government to operate the port 24/7. The rather large tidal difference makes this wish complicated. It has to be considered if this desire is reasonable. From a financial point of view it might be better to start with a tidal window; it is always possible to deepen the access channel in the future.

4.6 Layouts

In this section 4 sub-variants will be developed. First some general information on the sub-variants is given. In chapter 5 will be determined which sub-variant is most suitable for this project, by using a Multi Criteria Evaluation.

4.6.1 In general

The layouts that are developed in this section all basically fulfil the requirements posed in the above section. They differ for example in landfill/dredging ratio, positioning of the access channel and extension possibilities. When the design process started, it soon became clear that the area of land and sea that is reserved for this new port is far too big for the real necessary space as was calculated in chapter 3. Therefore is focussed on the water area and wet infrastructure in the following sub-variants. In any case the available land will be enough for the required and desirable facilities at land. After choosing the best wet sub-variant, the dry infrastructure and terminal layout will be developed in chapter 7.
Directly in front of the coast the sea is very shallow. Therefore in the following sub-variants it has been tried to find the most optimal relation between landfill and dredging. It might seem logical to develop a sub-variant in which the port is located at an island further seaward. This will be a very expensive sub-

variant though; not only because of the island, but also because of the necessary hinterland connections. Therefore, this sub-variant is not looked at further.
Since Haiphong is still growing in economic and industrial terms the extra landfill that might be necessary to reach a location with sufficient depth could be used for business and industrial activities. However near Doson some areas are still unoccupied at the existing part of the land as well. It will always be cheaper to first use these parts. It is hard to get insight in how much "new" land will be necessary and what the profits for that land will be. Because of that, in the following designs no extra attention will be paid on creating new land and no extra profits will be taken into account for these parts.
All sub-variants are connected to the land at approximately the same location. Therefore the hinterland connections for all layouts will be the same; they are described in section 4.4.1.
In the following sections the sub-variants will be shortly talked over. More detailed maps can be found in Appendix IX.

4.6.2 Sub-variant 1

The first sub-variant is an elongated one; in this way the deep water will be reached in the most economic way (see figure 4.3). The container quay is situated in the deepest part of the port basin; closer to the coast the general cargo vessels are moored. The pilot services are located at the end of the breakwater, so that they will have enough protection, but can assist the vessels immediately when they enter the port.
One of the main problems of this layout is the lack of information considering the morphology and sedimentation transport of the River Van Uc. It is possible that the port basin will have to be dredged too often, because of the accretion of the River Van Uc. It might be possible to lengthen the western breakwater up to the coast to protect the port basin of the sand. However, it might also be possible to heighten the sand bank that is black coloured at the following map. The river stream can then be directed southwards and will not bother the port basin as much. Extensive morphology studies must be done to find out about this. For now it is assumed that extra measures should be taken to protect the port basin and that maintenance dredging will involve considerable expense.
The quays can be extended landwards in future although the dredging that is needed in that case will be very intensively. Another option is, in case of a large capacity growth, to build an extra pier from the land to the western breakwater. The vessels could be berthed at the east side of this pier then.

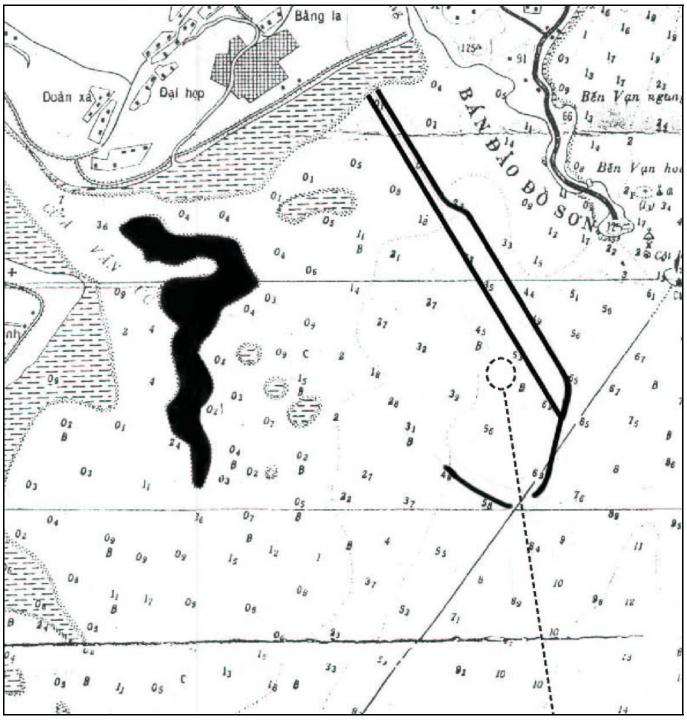

Figure 4.3: sub-variant 1

4.6.3 *Sub-variant 2*

In this sub-variant the quays are mostly positioned at right angles with the access channel in contrast to sub-variant 1. The access channel is of the same length as in sub-variant 1. The port basin is divided in the quays for general cargo, containers and inland barges. The pilot services could be located at the right side of the port along the breakwater.
In future the port could be extended by building quays instead of the eastern breakwater. It is also possible to moor smaller vessels outside the port basin at the north east side along the road that connects the port with the mainland.
Because the port is located rather far into the sea, there will be no shelter of the peninsula. Therefore the necessary breakwater length is rather long.

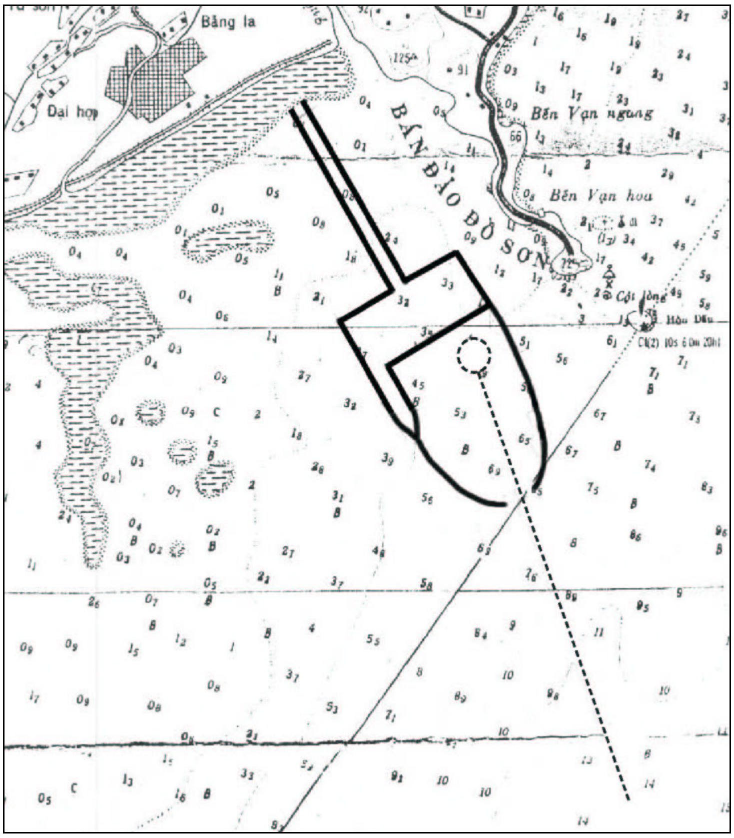

Figure 4.4: sub-variant 2

4.6.4 *Sub-variant 3*

In this sub-variant the port is positioned rather close to the coast. Little landfill, but a long access channel is the immediate result. To minimise the breakwater length the access channel has been positioned as close as possible to Doson peninsula. In that way the peninsula functions as a natural breakwater for the waves from the north east. The access channel is not positioned in the most favourable way (as was determined in 4.3.1) however. Although positioning of the channel in this way will decrease the construction costs of the breakwaters, it is questionable whether the downtime will not increase as a consequence of high waves from an unfavourable direction. This should be taken into consideration when evaluating the different sub-variants. Once again is said that the position of the access channel has been chosen to see if the peninsula could contribute as a natural breakwater, although it is known that this is not the most favourable position for the channel.
The passage to the small river at the hinterland has been kept free. In future it is possible to construct quays at the northeast side of the landfill, although extensive dredging will be necessary to reach that part.

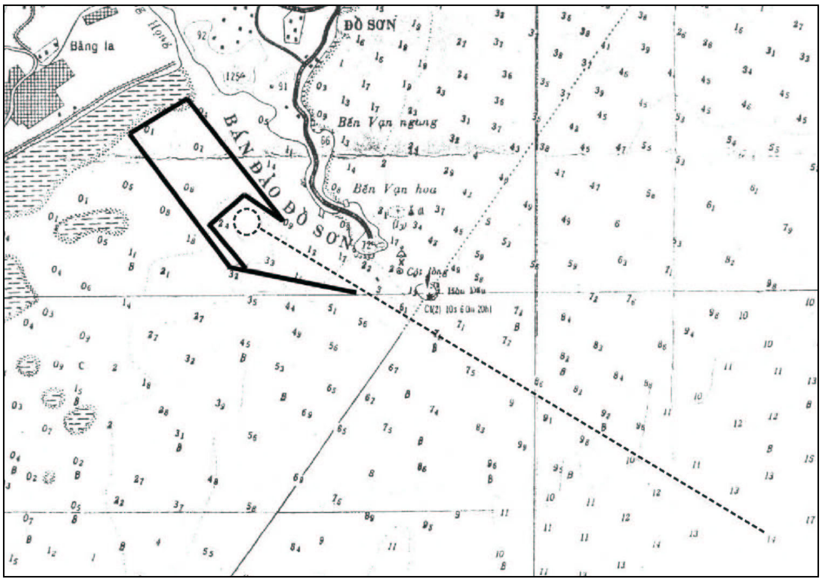

Figure 4.5: sub-variant 3

4.6.5 Sub-variant 4

In this sub-variant is chosen to set up the port basin more ample than in sub-variant 3. Use will be made of a detached breakwater. On the other hand the port is located in a rather shelter part of the sea, therefore the Doson peninsula can partly function as a natural breakwater. Therefore it is not necessary to extend the breakwater until it connects to the quay.

The port can be extended in future along the northeast side of the land. Smaller vessels could even be moored at the north side of the landfill. Another option is to build an extra quay from the general cargo quay to the breakwater.

Because the quays are located at the eastside of the landfill, morphology problems will be less than in sub-variant 1. The landfill functions as a natural protection against sedimentation in the port basin.

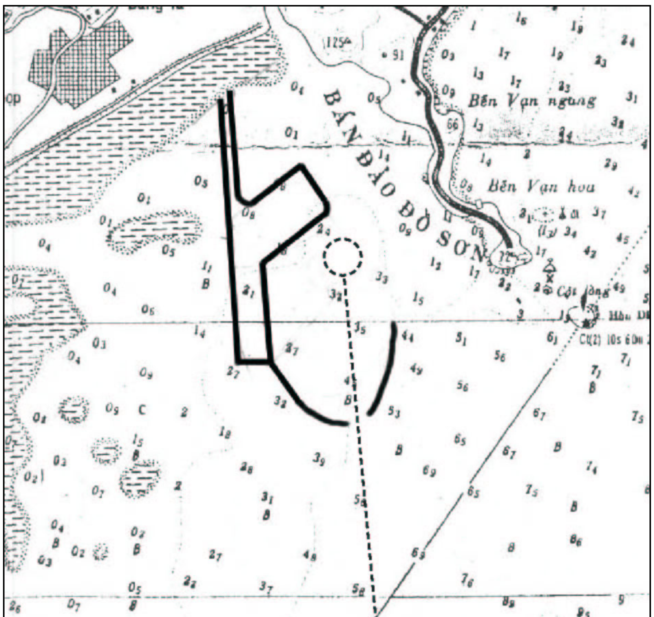

Figure 4.6: sub-variant 4

5 Multi Criteria Evaluation

5.1 Introduction

A Multi Criteria Evaluation (MCE) can be used to test the sub-variants by in advance formulated criteria. Because of this, it is easier to make a considered choice. Not all criteria have the same importance. By using different weighting factors it is possible to see how the opinion of different interested parties influences the choice of the most suitable sub-variant.
The costs will be looked at separately, because they usually have a large influence on the final result. Some sub-variants fulfil all the wishes and requirements of the authorities, but are far too expensive to construct. By separating the costs, it is possible to deliberate the value/ costs ratio of the sub-variants.

5.2 Qualitative properties

Costs blatant play a very important part in the process of choosing. Therefore it is not desirable to consider them in the first phase. When they are taken in consideration separately, it is possible to determine which sub-variant has the best value/costs ratio.
The non-cost criteria (qualitative properties) will be summarised here. The weighting factor for each property will be determined in section 5.3.

- **Functionality**
    - Accessible
    - Safe
    - User friendly
    - Extendible
    - Re-arrangable

The nautical functionality of the different sub-variants is one of the main properties in this evaluation. Nautical safety and manoeuvrability in the port basin are two of the factors that influence the accessibility. Special attention will be given to the safety of the layout. The positioning of the berths compared to each other and compared to the turning basin and access channel play an important part in this case.
The user-friendliness of the layout is influenced by the positioning of the berths and the available land for the terminal areas. The inland terminal for example is preferably located close to the container berths. Since the terminal layout will be designed in a further stage of the study, the user friendliness of the water layout will be looked at mainly in this evaluation.
Finally the possibilities for extension and re-arrangements should be overlooked. The layout is designed based on the throughput characteristics, which were calculated up to the year 2020. The port's lifetime will be longer though and therefore it is preferable that the layout is flexible for possible extensions and re-arrangements (in case the containerisation rate will change).

- **Construction**
    - Construction in phases
    - Reachable (construction site)

Phasing of the project is an important factor. The calculated capacity should be reached in 2020. Until then it is possible to construct the port in phases. In that case the first berths could be operational in 2010. This is necessary to relieve the existing port of Haiphong.
It is important that it is easy to reach the port for the construction workers and for the transporters of material. The logistics of the materials should be well organised to save time. Therefore hinterland connections during construction should be efficient, both on land and in the water.

- **Environment**
    - Space-using
    - Quiet (minor nuisance)

Per (sub-)variant will be overlooked what the influences on the environment are. Hereby it is important that the (sub-)variant causes as little nuisance as possible. Furthermore the space using should be looked at. How does this bother the environment? Is migration required for the villagers or fishermen?

- **Experience**
    - Prestigious

The Vietnamese government would like to build a port that has an international main port charisma. They would like to compete with the main ports of Hong Kong and Singapore. Therefore it is important that the design of the port has a certain prestigious charisma, although it is rather subjective to determine what prestigious is.

- **Sustainability**
  - Minor maintenance

Maintenance is a separate item. It involves both costs and qualitative properties. The costs will be overlooked in another section. When there is a lot of maintenance this will not only costs much, but it bothers the functioning of the port (f.e. downtime) as well.
The parts that bring on minor or more maintenance are dredging works (port basin and access channel) and the breakwaters. These both differ for the different sub-variants.

5.3 Evaluation

In this section the different sub-variants will be evaluated on the above-mentioned properties. A scale factor will be used to take into account the different degrees of importance.
For the calculations on dredging a depth of 13.55 m is determined and for the width 184 m (one-way channel). The required landfill is calculated to the level of +4.0 m CD. This might be too low, but the necessary height has not yet been determined. The mutual proportions are clear though, and in a later stadium the exact height can be calculated.
In the next table a score will be given for each sub-variant per qualitative property. A mark will be given on a scale of 1-10 (10 is best) for each (sub-)criterion.
Afterwards the weights of each property will be determined.

Table 5.1: scores per sub-variant

Main criterion	Sub-criterion	Sub-var. 1	Sub-var. 2	Sub-var. 3	Sub-var. 4
Functionality					
	Accessible	9	5	1	7
	Safe	7	3	1	9
	User friendly	7	7	5	9
	Extendible	9	5	1	5
	Re-arrangable	9	7	5	7
Construction					
	Construction in phases	3	3	7	7
	Reachable (site)	7	5	3	5
Environment					
	Quiet (minor nuisance)	9	7	3	5
	Space-using	9	7	3	7
Experience					
	Prestigious	9	7	3	7
Sustainability					
	Minor maintenance	7	5	1	3

To determine the mutual weight of each criterion the matrix below has been drawn up. A 1 is given when the criterion in the most left column is more important than the criterion in the upper row, a 0 when it is the other way around. In the most right column the scores have been summed up.

Table 5.2: mutual weights

		A	B	C	D	E	F	G	H	I	J	K	Σ
Functionality													
Accessible	**A**		0	1	1	0	0	1	0	0	0	1	**4**
Safe	**B**	1		1	1	0	0	1	0	0	0	1	**5**
User friendly	**C**	0	0		0	0	0	1	0	0	0	0	**1**
Extendible	**D**	0	0	1		0	0	1	0	0	0	1	**3**
Re-arrangable	**E**	1	1	1	1		0	1	1	0	0	1	**7**
Construction													
Construction in phases	**F**	1	1	1	1	1		1	1	1	1	1	**10**
Reachable (site)	**G**	0	0	0	0	0	0		0	0	0	0	**0**
Environment													
Quiet (minor nuisance)	**H**	1	1	1	1	0	0	1		0	0	1	**6**
Space-using	**I**	1	1	1	1	1	0	1	1		1	1	**9**
Environment													
Prestigious	**J**	1	1	1	1	1	0	1	1	0		1	**8**
Sustainability													
Minor maintenance	**K**	0	0	1	0	0	0	1	0	0	0		**2**

From the above table it can be seen that the property “reachable (site)” does not score at all. It will get a weight though; otherwise the marks for this property given in table 5.1 will be omitted. In the next table the scores have been multiplied by two, the property “reachable (site)” has got a score 1. This method is used to make sure that all properties will be taken into account.

Table 5.3: weighting factor

		Score Σ	Weighting factor
	Functionality		
A	Accessible	8	72
B	Safe	10	90
C	User friendly	2	18
D	Extendible	6	54
E	Re-arrangable	14	126
	Construction		
F	Construction in phases	20	180
G	Reachable (site)	1	9
	Environment		
H	Quiet (minor nuisance)	12	108
I	Space-using	18	162
	Experience		
J	Prestigious	16	145
	Sustainability		
K	Minor maintenance	4	36
		Σ=111	1000

Now the scores of table 5.1 will be multiplied by the weighting factors of the above table.

Table 5.4: final scores

Main criterion	Sub-criterion	WF	Score * WF			
			Sub-var. 1	Sub-var. 2	Sub-var. 3	Sub-var. 4
Functionality						
	Accessible	72	648	360	72	504
	Safe	90	630	270	90	810
	User friendly	18	126	126	90	162
	Extendible	54	486	270	54	270
	Re-arrangable	126	1134	882	630	882
Construction						
	Construction in phases	180	540	540	1260	1260
	Reachable (site)	9	81	63	27	45
Environment						
	Quiet (minor nuisance)	108	972	756	324	540
	Space-using	162	1458	1134	486	1134
Experience						
	Prestigious	145	1305	1015	435	1015
Sustainability						
	Minor maintenance	36	252	180	36	108
TOTAL		**1000**	**7632**	**5596**	**3504**	**6730**

The results of this evaluation show that sub-variant 1 scores best.

5.4 Costs

As was said, the costs will be looked at separately. They consist of many different aspects. The costs for the terminal and quay facilities, quay equipment, the transportation system at the terminal and hinterland connections will be largely the same for all sub-variants. The construction costs (dredging, landfill, breakwaters) however should be taken in consideration, because they differ for each layout. The costs for maintenance are an important factor as well, in particular the maintenance dredging. On the other hand one should not forget that the extra parts of landfill that are necessary in some of the sub-variants can be sold or rented out. This could lead to extra profits, although it is hard to predict this. Considering the available land in the existing area extra profits for landfill will not be taken into account.
In the next subsection several dimensions of the different sub-variants will be summarized. After that the landfill/dredging ratio will be determined. The results of these calculations will be overlooked in the third subsection, together with the other costs.

5.4.1 Analysis of dimensions and facts

This section shortly summarises the dimensions of the different sub-variants. This may help when the costs for the different parts have to be calculated.

Table 5.5: dimensions of the different sub-variants

		Sub-var. 1	Sub-var. 2	Sub-var. 3	Sub-var. 4
Access channel	Length (km)	4.5	5.0	10.0	8.0
	Dredging volume (m^3)	2.957.800	3.468.400	8.372.000	7.599.200
	Position	S	S/SE	SE/E	S
Inner channel	Length	2.3	2.3	2.3	2.3
	Dredging volume (m^3)	2.842.500	2.791.500	4.528.260	3.697.140
Breakwaters*	Length (km)	3.2	5.4	2.3	3.2
	Tonnage	612.095	1.007.365	241.878	422.943
Port basin	Surface (km^2)	1.81	1.58	1.20	1.97
	Dredging volume (m^3)	15.131.000	14.095.500	12.928.600	21.635.000
Landfill	Surface (km^2)	2.78	3.67	4.05	2.66
	Volume (m^3)	21.430.000	24.010.000	18.915.000	14.304.000

*) The calculation on the necessary tonnages per breakwater can be found in Appendix X.

5.4.2 Landfill/ dredging ratio

Since dredging and landfill both play a considerable part in the costs, it is important to deliberate all different aspects that influence the total costs of both. Not only should the costs per cubic meter mere be taken in consideration, but also aspects as maintenance.
The costs for dredging and landfill are as following:
Landfill $ 2-2.5 / m^3
Dredging $ 1.2-1.5 / m^3
These prices are based on Vietnamese contractors; the price for the same work done by international companies is 1.5-2 times higher.
As can be seen dredging is cheaper, but it needs yearly maintenance. Therefore it is important to get insight in the maintenance costs over a certain period.

In the following calculation this factor will be looked at. The average annual amount of sedimentation and accompanying dredging costs will be calculated. It should be said that this is a very basic calculation; an extended morphology study is required to get more insight in the situation.

River estuary Van Uc: sediment load 6.4 mln tons/year
*Assume that all of this sediment precipitates in an area of 8 * 11 km around the river mouth. Some sandbanks will catch more, but none of these sandbanks is located in the port basin or access channel of the port. So in practice the average volume will be a little less, on the other hand it might be possible that sediments from other rivers will flow to this area.*
Furthermore assume that this sediment holds 1.5 g/ cm^3.
The average yearly rise of the bottom level then becomes 4.85 cm.
The port is located relatively sheltered in relation to the northern rivers Lach Tray, Bach Dang and Lach Huyen (see map Appendix VII); the Doson peninsula functions as a natural dam and keeps the sediment at the north side of the peninsula. From the southern side however, more sedimentation can be expected, especially from the Thai Binh River. Exact numbers are not known, but considering the sand banks it is expected that most of the sediment load of this river immediately precipitates at the banks. The tidal currents eventually bring in sediment as well.
The total average sedimentation in the port area will be assumed at 0.1 m/yr.

The following table shows the necessary dredging per sub-variant per year, based on the dimensions of table 5.5.

Table 5.6: maintenance dredging volume per year

		Sub-var. 1	Sub-var. 2	Sub-var. 3	Sub-var. 4
Access channel	Length (km)	4.5	5.0	10.0	8.0
	Dredging volume (m^3) / yr	82.800	92.000	184.000	147.200
Inner channel	Length (km)	2.3	2.3	2.3	2.3
	Dredging volume (m^3) / yr	37.560	37.560	37.560	37.560
Port basin	Surface (km^2)	1.81	1.58	1.20	1.97
	Dredging volume (m^3) / yr	181.000	158.000	120.000	197.000
TOTAL (m^3/yr)		**301.360**	**287.560**	**341.560**	**381.760**

The following calculation will be done for a period of 30 years. The port will probably function longer than that, but it is hard to survey the economic developments over a longer period.
Of course interest plays an important part in this calculation.
Therefore the following formula[3] is used to count back the sums of money to the base year 2020.

$$S = s * \frac{100}{\delta} * \left(1 - e^{-\frac{\delta T}{100}}\right)$$

S = *capitalized maintenance costs* *[$]*
s = *annual expense* *[$]*
δ = *disconto percentage* *[%]*
T = *lifetime* *[yrs]*

$$S = s * \frac{100}{3.5} * \left(1 - e^{-\frac{3.5*30}{100}}\right) \approx 18.57s$$

The following table summarizes all above calculated costs concerning landfill and dredging.

Table 5.7: costs per sub-variant

		All prices in $			
		Sub-var. 1	Sub-var. 2	Sub-var. 3	Sub-var. 4
Construction costs	Landfill a $ 2.25/m^3	48.217.500	54.022.500	42.558.750	32.184.000
	Dredging a $ 1.4/m^3	29.303.820	28.497.560	36.160.404	46.103.876
Maintenance costs (30 yrs)	Dredging 0.1 m/yr a $ 1.4/m^3	7.834.757	7.475.985	8.879.877	9.924.996
TOTAL costs ($)		**85.356.077**	**89.996.045**	**87.599.031**	**88.212.872**

5.4.3 Costs evaluation

Parts of the costs have been calculated in section 5.3.2, namely the costs concerning dredging and landfill. The costs of breakwaters however will be taken into account as well, because of the large differences per sub-variant.
Assumed is a price of $16/ ton for the construction costs of a breakwater.

Table 5.8: costs

Costs	in mln $	Sub-var. 1	Sub-var. 2	Sub-var. 3	Sub-var. 4
Capital investment	Dredging	29.3	28.5	36.2	46.1
	Landfill	48.2	54.0	42.6	32.2
	Breakwaters	9.8	16.1	3.9	6.8
Maintenance (30 yrs)	Dredging	7.8	7.5	8.9	9.9
	Breakwaters	p.m.	p.m.	p.m.	p.m.
TOTAL COSTS (mln $)		**95.1**	**106.1**	**91.6**	**95**

As can be seen from the table above, sub-variant 3 is the cheapest in terms of costs. It should be kept in mind that this involves the costs of landfill, dredging and breakwaters only.
Furthermore, the construction costs have not been discounted over the construction period. In the calculation stated above, has been assumed that all costs will be paid for by the year 2020. Depending on the phasing of the different sub-variants, the investments will be spread over the years 2004-2020.

5.5 Value/ costs ratio

In this section the value/costs ratio will be determined. This will give insight in the way the costs balance the value of the project. In the first table (5.9), the plain costs are compared to the value.

Table 5.9: plain costs compared to value

RATIO	Sub-var. 1	Sub-var. 2	Sub-var. 3	Sub-var. 4
Value	**7632**	5596	3504	6730
Total costs (in million $)	95.1	106.1	**91.6**	95
Value/ costs ratio	**80**	53	38	71

Table 5.10: rankings

RANKING	Sub-var. 1	Sub-var. 2	Sub-var. 3	Sub-var. 4
Value-method	**1**	3	4	2
Costs	3	4	**1**	2
Value/ costs ratio	**1**	3	4	2

As can be seen, the ranking on the basis of costs is different to the others. It is up to the client of this project to decide if the extra value of sub-variant 1 counterbalances the extra costs involved. For now it will be assumed that the choice for the most suitable sub-variant will be made on the basis of the value/ costs ratio ranking.

5.6 Sensitivity analysis

For this sensitivity analysis two other sets of weighting factors have been determined to check if the above evaluation has not been influenced by the subjectivity of the chosen weights.
In one set the weights are the same for each property (W_{eq}). The other set is determined from the port authority's point of view (W_{pa}). The port authority wants the new port to be safe and accessible. The nautical functionality is the main property for them. Furthermore they will have an interest in construction the port in phases. In that way the first berths will be operational in 2010.
The results of the different weighting sets are shown in table 5.11. The exact weights and score tables can be found in Appendix XI.

Table 5.11: results different weighting sets

	Results	Sub-var. 1	Sub-var. 2	Sub-var. 3	Sub-var. 4
Weights section 5.2	**W**	**7632**	**5596**	**3504**	**6730**
	Value/ costs ratio	109	77	64	95
	Ranking	**1**	3	4	2
Equal weights	**W_{eq}**	**7735**	**5551**	**3003**	**6461**
	Value/ costs ratio	110	76	55	91
	Ranking	**1**	3	4	2
Weights port authority's point of view	**W_{pa}**	**7524**	**5198**	**3142**	**7396**
	Value/ costs ratio	107	71	57	104
	Ranking	**1**	3	4	2

In the following chart these results have been plotted. As can be seen the changes in weights do not have a major influence on the different results. The ranking of the four sub-variants stays the same for each set of weights.

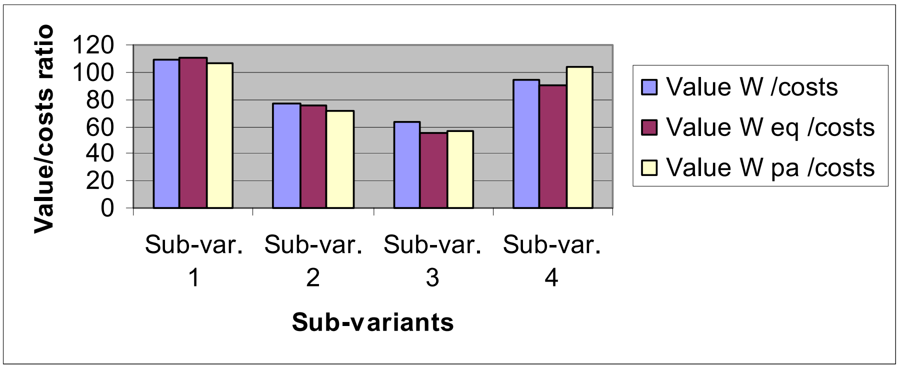

Figure 5.1: value/ costs ratios for the different weighting sets

6 Simulation of the access channel [29]

6.1 Introduction

The access channel is one of the main components of a port. Because of the large amounts of dredging, high costs are involved. Therefore it is worthwhile to examine the dimensions in more detail. In that way the design of the channel can be optimized without exceeding the acceptable waiting times for the different vessels. This optimizing will be done by means of a computerized simulation program, called Harborsim. This program has been developed by the Delft University of Technology and is programmed in the computer language Prosim.
The following section will describe the working of Harborsim shortly. After that, the specific situation for this study will be described and the site conditions that play part in this simulation will be determined. Finally the results of the simulation runs will be discussed in the last section.

6.2 Working of Harborsim

This section will give a short description of the working of Harborsim.

6.2.1 Introduction Harborsim

Harborsim is a model that generates vessels according to a certain arrival pattern. When the vessel is selected by the generator, it first enters the anchorage of the model, and is placed in a queue for the quay. The vessel waits in this queue until there is space available at the quay. When the model determines that this space is available, the vessel is placed in the queue for the access channel. The access channel is divided into different sections. For each section certain traffic rules, concerning overtaking and encountering, have been formulated. The Q-master checks whether the first vessel in the queue is able to cross all sections without having to wait en route. When the first vessel is not able to go, the model checks the second vessel and so on. When a vessel can leave the queue, the model makes a reservation in each section for the period that the vessel abides in each section. The vessel will moor at the quay and stay there for the duration of the vessels service time. After that, the vessel will be placed in the queue for departure. Again the different sections will be checked to determine whether the vessel is able to sail the complete channel without being disturbed by unwanted meetings with other vessels. When this is possible the model reserves the sections for the time that the vessel will occupy these sections. After the vessel has finished the complete route, the data will be saved and the vessel will be removed from the model.

6.2.2 Terms

In this subsection several terms and components used in this model will be defined.

Channel
The channel is divided in several sections. Each section has its own traffic rules, which will be explained below. Each type of vessel has its own route of following sections to the quay. Per vessel it has been determined how long it will take the vessel to cross the section.

Section
For each section one of the following two qualities, namely sailing or manoeuvring, is operative.
"Manoeuvring" implies that in that particular section the vessels are manoeuvring (for example in the turning circle or mooring area); no other vessels are allowed to cross the section when a vessel is manoeuvring. Only 5 minutes after the vessel has left the manoeuvring section, the next vessel is allowed to enter the section.
When the quality "sailing" is operative for a certain section, more than one vessel is allowed to make use of the section at the same time. However, for these sections certain traffic rules will be in force. In the model for each section can be determined whether the vessels are allowed to overtake and/or encounter or not. If not, than a minimum distance of 5 minutes of sailing time is required in between the two vessels. The vessels in the model are not able to reduce their speed when encountering is not allowed; they sail at a constant speed. When overtaking is not allowed in a certain section, one way traffic in alternately direction will be applied for that section.
The traffic rules can be tuned for each different combination of vessels.

6.2.3 Modules

The model consists of several modules. Each module describes the behaviour of a certain component of the model. The components each have their own characteristics. The most important modules of the model will be shortly talked over in this subsection.

Main The module Main starts the model. It opens all relative files and reads the input. The actual simulation is started by the component Main when it activates the generator. When the duration of the process of simulation has finished the module saves all data and activates the Results file.

Termprocess In this module the terminal process is handled. The module keeps up the available quay length every time a vessel arrives or leaves the quay.

Genprocess This module describes in what way the generators generate a new vessel and which criteria play part in that process. Especially the arrival pattern (inter arrival time) of the different vessels is an important factor. In this model use has been made of the following distribution functions for the arrival pattern: the Erlang Distribution function (for container vessels) and the Negative Exponential Distribution function (for general cargo vessels).

Trafficinprocess This module checks the incoming traffic. The Q-master checks for these incoming vessels whether it is safe for the vessel to enter the quay with respect of the traffic rules.

Trafficoutprocess This module works like the trafficinprocess module, the only difference is that in this case it concerns the outgoing traffic.

Q-masterprocess The Q-master is the keeper of the quays; he checks the availability at each quay. When there is space, he sends a vessel from the “quay” queue to the berth.

6.2.4 Data input

In Harborsim three input files are used to collect the input of the simulation.

Dataport This file consists of all information on the quays in the simulation. The length of each quay is written down. Furthermore the duration of the simulation run is established in this file.

Dataship In this file all characteristics of the vessels have been collected. The destinations, length and arrival patterns for example are all given for each vessel.

Datastretch This file contains the data on each section. It describes the traffic rules and the required time to cross a section for each vessel.

6.3 Description of the access channel

The access channel that will be modelled for this study is divided in 10 sections (figure 6.1). Container vessels follow the route 1-2-3-4-5-6; general cargo vessels sail the sections 1-2-3-4-7-8-9-10. Sections 4 and 8 function as turning circles, 6 and 10 are the manoeuvring basins in which the vessels moor.

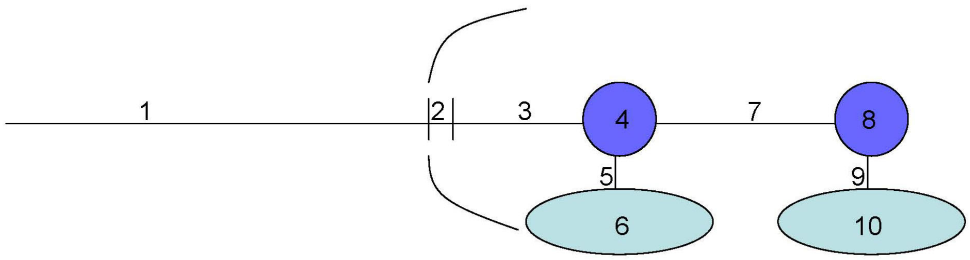

Figure 6.1: division sections

6.3.1 Site conditions

In the model several conditions can be adjusted. These are:

- Conditions per section
  - Sailing
    Traffic rules that give certain vessels permission to encounter and/ or overtake.
  - Manoeuvring
- Tidal window
  This condition does not allow vessels to enter the channel when the water level in each section is below the window level.
- Quay length

The turning circles (section 4 and 8) and the berthing area in front of the quay (section 6 and 10) are manoeuvring sections. In the other sections the quality "sailing" is in force. In these sections traffic rules determine whether vessels are allowed to encounter and/or overtake. These rules will be changed per run.
The model contains a tidal window as well. One can decide to close the channel when the water level underspends a certain depth.
Finally one can change the quay length. This influences the availability of the quays and therefore the "quay" queue.

6.3.2 Base conditions

In the model a base situation will be used. In this situation the quay lengths, will be used as following: (design length + 15m) * number of berths as was calculated in chapter 3. This means a length of 1260 m for the container quay and 603 m for the general cargo quay.
Chosen is to start without using a tidal window. The dredging costs will be enormous however when the vessels are allowed to enter the port 24/7.
As was mentioned above, the sections 4, 6, 8 and 10 are manoeuvring only. The adjustment for the other sections is "sailing", but the traffic rules are set in such way that encountering and overtaking is not allowed for any vessel type.
The maximum waiting time as percentage of the service time is 10% for container vessels and 25% for general cargo vessels.
Use has been made of an Erlang distribution for the arrival pattern of the containers vessels; for the general cargo vessels this is a Negative Exponential Distribution.
The following table summarizes the chosen start conditions for this base model. Table 6.2 shows the results for this set of conditions. The waiting time as percentage of the service time satisfies the above-mentioned demand of 10% or 25%.

Table 6.1: site conditions base situation

Traffic rules	Manoeuvring	Sections 4, 6, 8, 10
	Sailing	Sections 1, 2, 3, 5, 7, 9
	Overtaking	not permitted for any sailing section
	Encountering	not permitted for any sailing section
Tidal window		no tidal window active
Quay length	Container	1260 m
	General cargo	603 m

Table 6.2: results base situation

	Container	General cargo
Average number of ships passed per year	621	98
Mean service time (minutes)	1952	9281
Mean waiting time over all runs (minutes)	44.6	1972
Waiting time as % of service time (%)	2.3	21.2

As can be seen the waiting time as percentage of the service time is rather low for the container vessels. For the general cargo however, the percentage approaches the border of 25%. Since the arrival pattern of according to an NED pattern is very whimsical, this might be a little too high. Over a period of ten years it does fulfil the posed condition, but in several years the waiting times are enormous. It is up to the port authority to decide whether this is acceptable or not. For now, a more optimal situation will try to be found in the next section. In several runs the different conditions will be varied.

6.3.3 Verification and validation

Verification covers the check whether the model does what it should do, f.e. does the vessel follow the correct route and does the vessel leave the model when the simulation is finished. Since Harborsim is an existing model, this verification has already taken place.
The validation checks whether all parameters have been regulated in a proper way. Since this model does not simulate an existing situation (the channel has not been built yet), the results can not be compared with a real-time situation. Therefore the results will be compared to the results of the queuing theory in chapter 3.
The quay lengths in the model differ from the ones used in chapter 3; this is because the model does not use the 15 m that are counted in chapter 3 as the distance in between two moored vessels. In chapter 3 for the container vessels a waiting percentage of 6% was found. This is a little more than the 2.3% that was found in the base run of this model (table 6.2). This can be explained in the simulation runs in which it is sometimes possible to moor five vessels along the quay, where in the queuing theory a maximum number of four vessels is handled at the same time. The program moors the vessels next to each other alongside one long quay. When five smaller vessels arrive they can be handled at the same time. The queuing theory makes use of four individual berths. When four smaller vessels arrive more space is left in between each vessel. Therefore the waiting times in the queuing theory will be a little higher.
The general cargo vessels have a little higher waiting time in the program than was calculated on base of the queuing theory (21% versus 16%). The moving over of smaller vessels does not work the same as with the container vessels, since much less general cargo vessels arrive per year. Higher waiting times are caused by the channel and its traffic rules. Because of all container vessels, the sections 2, 3 and 4 are continuously operating at their full capacity. Therefore some general cargo vessels will have to wait until they are able to sail the complete channel, even though there is space at the quay.
Although the results differ slightly, it can be concluded that the model works in a proper way and that the results from the model are valid.

6.4 Results

As can be seen in section 6.3.2, the waiting times as percentages of the service time in the base run fulfil the demands. In this section several runs will be done to observe the behaviour of the waiting time and to check whether it is possible to optimise the dimensions of the channel.
Changes will be made in each of the conditions or in a combination of them.

The results of the below mentioned runs can be found in table 6.3. In Appendix XII a more extensive table can be found.
In the first couple of runs (1-4) the tidal window will be slowly increased. It can be seen that the waiting times increase only slightly. Run 4 with a tidal window of +1.40 m CD shows that the waiting time for container cargo runs up too high (11.5%). This has been visualised in the figures 6.2 and 6.3. The horizontal line represents the maximum allowed waiting time as percentage of the service time. The x-axis represents the water level relative to Chart Datum below which no entering of the channel is allowed.

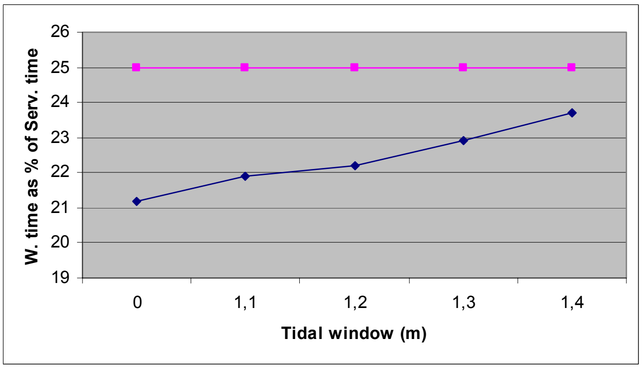

Figure 6.2: general cargo, tidal window in relation to waiting time as percentage of service time

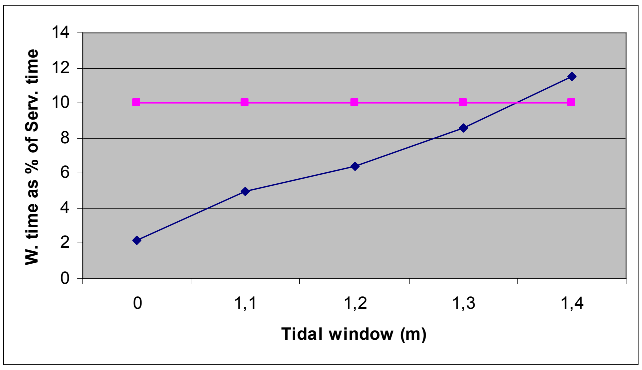

Figure 6.3: container cargo, tidal window in relation to waiting time as percentage of service time

Since the waiting time for general cargo is rather high as well, the length of both quays will be enlarged in run 5, till the lengths as they were calculated in section 3.2.6. This changes the waiting times of the general cargo vessels largely. The influence for the container vessels is smaller, although the percentage has been decreased enough to fulfil the 10% demand.
Figure 6.4 shows which period of the tide the water level underspends the +1.40 m CD level (horizontal line).

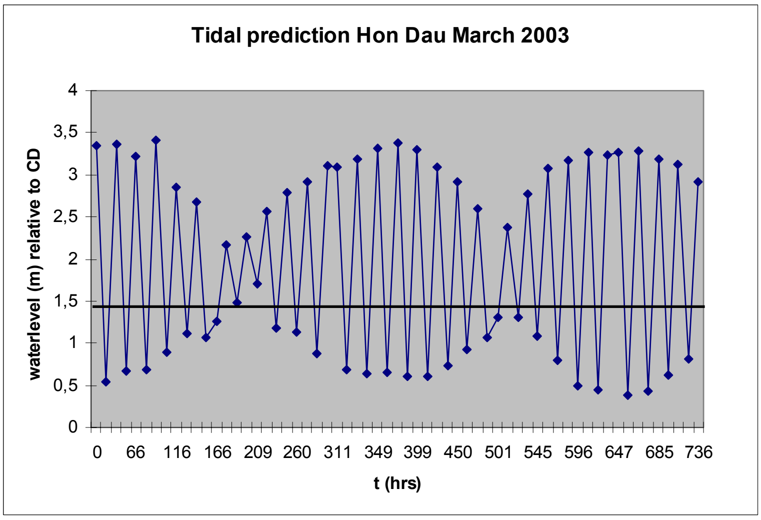

Figure 6.4: tidal window of +1.40 m CD

The occupation level of several sections seems to be the bottleneck for the waiting times of the container vessels. In run 6 for all "sailing" sections the vessels are allowed to encounter and overtake. Now the waiting times for container vessels indeed decrease.
The waiting time for general cargo only decreases slightly. Therefore it is not plausible that changing of the traffic rules in section 7 highly influences the results. The same counts for section 2 and 3. These sections are very small; therefore the chance that vessels will overtake or encounter in these sections is small.
In the next run (no. 7) the above argumentation will be tested. Only in section 1 overtaking and encountering will be allowed. The results are nearly the same as for run 6. Therefore it can be

concluded that only section 1 can influence the waiting times when the traffic rules are changed. The size of influence of section 1 will be looked at now.
In run 8 the tidal window will be driven up to +1.50 CD. It can be seen that the waiting time for containers already exceeds the 10%. The width of the channel should be nearly doubled to make it possible for the vessels to encounter and overtake. This broadening will bring a large amount of extra dredging work with it. It does not counterbalance the "profit" of the little lower waiting times. Furthermore, as can be concluded from run 8, there is no worth mentioning profit that a larger tidal window could be used. From the above runs can be concluded that it is not worthwhile to dimension (parts of) the channel as a two-way channel.

Table 6.3: results optimisation runs

Run	**Tidal window** No entering allowed below:	**Overtaking/ encountering***	**Container quay length (m)**	**Gen. cargo quay length (m)**	**$W_{container}$ (%)**	**$W_{gen.\ cargo}$ (%)**
base	no tidal window	not allowed	1260	603	2.3	21.2
1	+1.10 m CD	not allowed	1260	603	**5.0**	21.9
2	+1.20 m CD	not allowed	1260	603	6.4	22.3
3	+1.30 m CD	not allowed	1260	603	8.6	22.9
4	+1.40 m CD	not allowed	1260	603	**11.5**	23.7
5	+1.40 m CD	not allowed	1401	678	9.9	12.9
6	+1.40 m CD	allowed in sections 1, 2, 3, 7	1401	678	8.0	12.1
7	+1.40 m CD	allowed in section 1	1401	678	8.1	12.2
8	+1.50 m CD	allowed in section 1	1401	678	**10.5**	12.7

$W_{container}$ Waiting time as percentage of the service time for the container quay
$W_{gen.\ cargo}$ Waiting time as percentage of the service time for the general cargo quay
*) For overtaking and encountering no discrimination has been made between the different types of vessels. For all types the same rules count at the same time.

Summarizing, the above runs show that the following site conditions create the most optimal design for the access channel in this situation (run 5):

- one-way channel in which the vessels are not allowed to overtake or encounter
- tidal window in which it is not allowed to enter the channel when the water level is lower than +1.40 m
- container quay length 1401 m, general cargo quay length 678 m

In the following figures the time-advancing average of the waiting time as part of the service time has been put on the y-axis, the x-axis represents the time (≈ 3 years). It can be seen that the pattern for the container vessels is very flat, except from the little discontinuities when a new run starts. The general cargo pattern is more whimsical, which can also be seen from the results in Appendix XII.

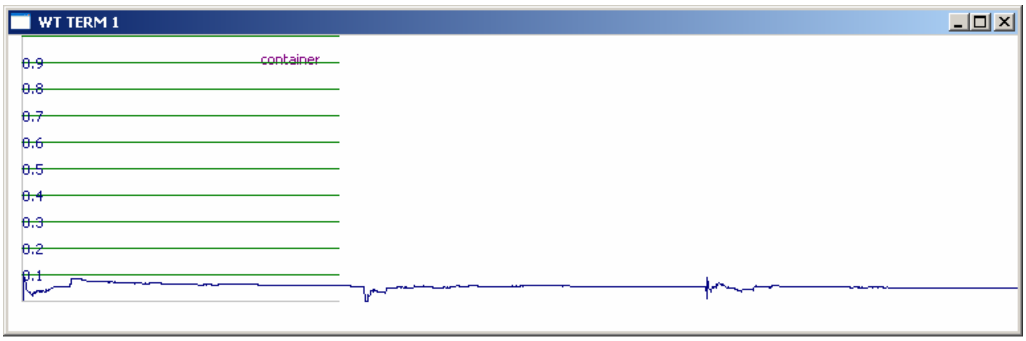

Figure 6.5: flat pattern container cargo waiting times

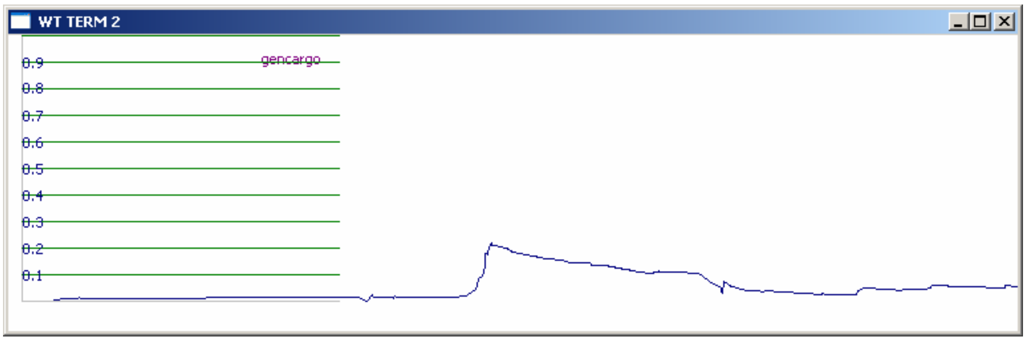

Figure 6.6: whimsical pattern general cargo waiting times

In the Appendix some other charts have been enclosed as well. These contain the results of a short run of only 1 month (under the same conditions as run 5). These figures show the presence of vessels in some sections during this month.

7 Terminal layout, construction planning and cost estimation

7.1 Introduction

In the first section of this chapter the terminal layout will be determined. Since no further research on this subject has been done yet, only a rough layout will be designed. Detailed calculations on quays, foundations, landfill etc. have not yet been done.
Afterwards an executive planning will be given. This will give insight in the construction order and time scale. The results of this planning will be visualised in a bar chart.
Until now only the costs of the dredging, landfill, hinterland connections and breakwaters have been determined roughly (chapter 5). In section 7.5 the costs of the whole project will be estimated at component level.

7.2 Terminal layout

This section will give a map of the preliminary design of the terminal layout.
The necessary facilities for this port are grouped per terminal; the port will consists of two separately operating terminals, namely the container terminal and the general cargo terminal. Furthermore the general facilities are gathered. Some of them will be shared by the two terminals, others will be operating separately. Per group the necessity of the different facilities to be located next to another has been reflected. The surface that should be reckoned with per facility can be found in chapter 4.

<u>Container terminal</u>
- Container quay
- Apron area
- Container Freight Station (CFS)
- Storage for import, export, domestic, hazardous cargo, reefers and empty containers

These facilities should be connected to the railway station. Trucks should be able to reach the terminal and pick up the containers. Empties can be put down outside the terminal area. The storage for hazardous cargo should be located separately.

<u>General Cargo terminal</u>
- General cargo quay
- Apron area
- Transit shed
- Open storage

These facilities should be connected to the railway- and truck station.

<u>Inland barge terminal</u>
- Inland barge quay
- Apron area

The terminal should preferably be situated close to both the general cargo and the container quay.

<u>Hinterland connections</u>
- Railway station (office, classification yard, garage)
- Truck station for each terminal (parking, garage, petrol station, office)
- Road connection to the main road Doson-Haiphong
- Rail connection to the Haiphong railway station

Trucks are allowed to enter the terminal and pick up cargo at the general cargo storage. Therefore the road network at the terminal should be sufficient for this kind of transport. Trains are not allowed in the storage areas. The railway station is preferably located outside the gate.

<u>General facilities</u>
- Gates for both general cargo and container terminal
- Offices for administration and customs
- Quay and office for towing, pilot and oarsmen services
- Garages
- Terminal infrastructure (internal roads)

All facilities should be connected to the offices and main gate by good infrastructure.

The tugboat and pilot services should preferably be located close to the port entrance, immediately behind the breakwater. The oarsmen operate in the berthing area.

<u>Extra facilities (outside the gate)</u>
- Water supply
- Power supply

All these components have been arranged in the following layout. It can be seen that part of the layout is hatched. This part is fallow land; it can be used in a later stage when expansion is necessary.
Since the expected import is much larger than the export many empty containers have to be stored. Part of this storage will be done outside the terminal at the main land, where enough land is available. Just before transportation the empty containers can be stored in the area near the quay.
In between the inland barge quay and the container quay, part of the quay will not be used yet. This part can be used when expansion is necessary or when the containerisation rate changes and more container vessels are expected. In that situation the container quay is still one densed quay.
A larger version of this map, the detailed layout and a 3 dimensional visualisation can be found in Appendix XIII.

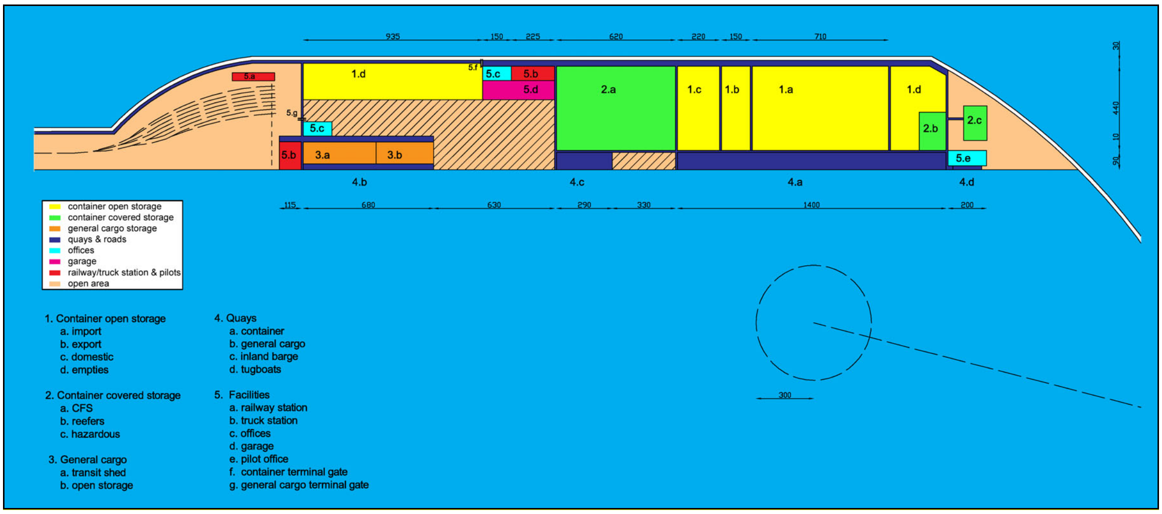

Figure 7.1: terminal layout

7.3 Construction planning

The complete construction period of this project can be subdivided into two main periods. The first period starts as soon as the decision has been officially made to carry out the project and will finish in 2010. By that time the construction of at least two container berths should be finished, although it is preferable to finish the construction earlier.
The second period consists of the years 2010 to 2020. In 2020 the complete port should be up-and-running, including all facilities outside the port that have a major influence on the working of the port.

The first subsection summarises all facilities that are necessary in 2010. After that a construction planning for this period will be made. In the second subsection the period 2010-2020 will be overlooked.

7.3.1 Construction planning 2004-2010

The following components should be finished to be able to operate the first part of the port in 2010:
- Access channel
- Breakwaters
- Landfill
- 2 container berths
- 1 inland barge berth
- Pilot and tugboat service berths
- 1/3 of all container storage facilities as they are calculated for 2020
- Offices and supporting facilities

- Truck station with half the capacity that is necessary in 2020
- Sufficient road connection to Haiphong

As can be seen no general cargo facilities will be constructed before 2010. This is because it is expected that the existing Haiphong port will be able to handle the general cargo.
Furthermore the construction of the railway hinterland connection, which is a large project on itself, will probably not be finished before 2010. However, since just a part of the total transport to the hinterland will be done by rail, this can be done by truck at the start. It is desirable though, to finish the construction of the railway as soon as possible.
Supply of construction materials should be possible, before can be started with the actual construction. Therefore it is important to connect the location with the existing road and to dredge a temporary channel, which can be used by smaller vessels that transport materials. Furthermore power and fresh water should be available as soon as possible.
A bar chart of this planning can be found in Appendix XIV. This planning is divided in periods of half a year. As can be seen this planning strives for an operational port in 2009. The map of the layout of the terminal in 2010 can be found in Appendix XIV as well.

7.3.2 Construction planning 2010-2020

After 2010, when the first part of the port is operational, it should be taken into account that the further construction duties should bother the port functioning as less as possible. Furthermore it is desirable to make a quick start with constructing the general cargo quays because it is expected that the capacity of the existing Haiphong port will soon be inadequate. After that the remaining two container berths can be constructed, one by one. Simultaneously the storage facilities for each extra berth can be constructed.
The detailed phasing of this part of the project depends on the actual growth of the cargo. When the cargo throughput is larger than expected, one can try to finish the construction of the berths as soon as possible. A construction period of ten years for this part of the project is relatively large; therefore it is possible to adjust the planning to the development of the cargo transport.

7.4 Costs[7]

To define the scope of this project and the target budget a project cost estimate will be carried out in this section. The next table presents the estimation of the costs of the different components of this project. A more specified list of the below mentioned components can be found in Appendix XIV.
This estimate only consists of the components of this port. These components obviously do not cover all costs involved in this project. The unit price is, as far as possible, based on the prices offered by Vietnamese contractors.

Table 7.1: cost estimation

	Facility	Quantity	Unit price ($)	Costs ($)
Wet infrastructure	Dredging	20.931.300 m^3	1.4 / m^3	29.303.820
	Breakwaters	611.607 ton	16 / ton	9.785.712
	Navigational aids	p.m.	-	-
Port basin	Container quays	1401 m^1	27.800 / m^1	38.947.800
	GC quays	678 m^1	25.000 / m^1	16.950.000
	Inland barge quays	290 m^1	20.500 / m^1	5.945.000
Container terminal	Apron area (equipment p.m.)	126.090 m^2	100 / m^2 (40 cm thick)	12.609.000
	Storage area	837.995 m^2	13.5 / m^2 (5 cm thick)	11.312.933
	CFS	279.714 m^2	320 / m^2 floor area	89.508.480
	Hazardous cargo	20.000 m^2	400 / m^2 floor area	8.000.000
	Reefers	28.000 m^2	320 / m^2 floor area	8.960.000
General Cargo terminal	Apron area (equipment p.m.)	26.970 m^2	100 / m^2 (40 cm thick)	2.697.000
	Transit shed	42.270 m^2	320 / m^2 floor area	13.526.400
	Open storage	35.225 m^2	13.5 / m^2 (5 cm thick)	475.538

Inland barge terminal	Apron area (equipment p.m.)	8.700 m^2	100 / m^2 (40 cm thick)	870.000
Hinterland connection	Truck station (petrol station, garage, office p.m.)	33.550 m^2	27 / m^2 (10 cm thick)	905.850
	Railway station	Station and classification yard	36.000.000	36.000.000
	Road	6300 m asphalt bridge 200 m	27/m^2 (10 cm thick) 1000 / m^2	3.301.000
	Railway	19800 m bridge 200 m	2.400 / m^1 15.000 / m^1	50.520.000
	Inland waterway	p.m.	-	-
General facilities	Landfill	21.430.000 m^3	2.25 / m^3	48.217.500
	Gate (+ fence)	p.m.	-	-
	Offices	22.500 m^2	680 / m^2 floor area	15.300.000
	Pilot, towing and oarsmen services	quay 150 m^1 3 offices (à 150 m^2)	20.500 / m^1 680 / m^2 floor area	3.381.000
	Terminal infrastructure	internal roads 10.000 m asphalt	27 / m^2 (10 cm thick)	2.700.000
	Harbour equipment	p.m.	-	-
	Garages	p.m. (private tender?)	-	-
Extra facilities	Water supply	p.m.	-	-
	Power supply	p.m.	-	-
Total costs of components				**$409.217.033**

(p.m.: pro memoria)

The total of 410 mln US dollar is the estimated sum of the construction costs of above-mentioned components. Maintenance costs are not included, neither are the costs of the components marked with p.m. (pro memoria). Discounting over the construction period has not been taken into account.

7.5 Risks and remedies

When the feasibility of a certain project is being determined, it is important to map the risks that are involved in carrying out the project. In this section some of the most important risks have been summarised. It has to be said that the below presented list of risks is definitely not complete. It only exists of risks that are specific for this project. Besides below-mentioned risks the “standard” risks of safety, dispossessions, claims, strikes, delay due to archaeological findings, rate alterations etc. should be taken into account.

Risk concerning the feasibility of the project

- **Throughput expectation**
  One of the largest uncertainties of this study is the expected throughput for the port. This figure depends on so many different factors, that it is very difficult to forecast.

  The forecast that has been made in this study refers to the throughput for the year 2020. In the following 17 years many factors can change though. The Vietnamese economy has been growing tremendously in the last decade. It is questionable if this will go on. The Vietnamese government cannot influence this all by her self. The world economy plays part in the growth as well. The SARS outbreak for example influenced the economy in Asia largely. Although the Vietnamese government regulated the outbreak of SARS in Vietnam quickly, the trade and tourism industry suffered from the disease for several months.
  World wars and economic depressions have not been taken into account in the in chapter 2 carried out analysis.
  A remedy will be to anticipate on the fluctuations in the (world) economy. Phasing of the construction will largely help to catch unexpected changes in the throughput. When the amount of cargo to be handled is disappointing, the construction of a next phase can be rescheduled. When the throughput exceeds the expectations the layout of the port contains room for extension.

<u>Risks concerning the construction of the port</u>

- **Delay due to the weather conditions**
  The Vietnamese coast is being afflicted by storms and typhoons quite often. This will not only delay the construction, but could also damage already constructed elements of the port.
  While formulating the construction planning, this should be taken into account. Especially the summer months are known for their unpredictable weather. Difficult construction processes should preferably be planned in the calm season. Furthermore it is important to construct the buildings and sheds in such way that they are dimensioned to withstand strong winds.
- **Delay due to mines**
  Vietnam is a former war country; therefore the risk is present that mines are located in the port area. Research should be done to avoid problems during construction.
- **Construction failures due to lack of adequate data**
  There is surely more data in stock on wind, waves and tides than was used in this study. It is questionable however, whether these data will be sufficient. Because data collection has not been carried out very long, it might be difficult to draw the right conclusions. Because of that, mistakes in the construction could arise.
  Furthermore, because too less is known on the morphology, the maintenance dredging works could be more extensive than expected.
  This lack of knowledge can be overcome as much as possible by using computer models on wind and waves, and by using the experience that has been gained during the construction of other projects in the surrounding area.

8 Conclusions and recommendations

8.1 Introduction

The objective of this study was to determine the feasibility of a deep-water port in the Haiphong area. The conclusions of this study will be presented in this chapter. The question whether this project is feasible or not will be answered in the final conclusion. In section 8.3 recommendations will be given which can be used as a guideline in further research.

8.2 Conclusions

- In Vietnam both international and domestic trade have grown tremendously in the last fifteen years. Therefore the throughput in Vietnamese ports is increasing rapidly. The GDP growth for the Haiphong area is higher than for Vietnam. Since the port will serve a large hinterland (with lower GDP growth than Haiphong) the expected cargo growth should not be calculated too optimistic.
  The containerisation rate for cargo worldwide is still growing, especially in developing countries where the containerisation rate is well below the international level. Therefore the container throughput will grow relatively fast compared to the general cargo. The main focus of the new port will be on container transport.

- The existing Haiphong port strongly exceeds its own capacity. At the moment the port is already operating above its maximum designed capacity. The foresight is that the port will not be able to handle the expected container throughput anymore in the very near future.

- Considering the expected throughput for the complete Haiphong area in 2020 (33.5 mln tons) and the from that expectation ensured cargo flow, it does not seem realistic to expect 80.000 DWT vessels in the new deepwater port. Therefore a design vessel of 54.000 DWT (4.500 TEU) for container ships and 30.000 DWT for general cargo ships has been used in this study.

- The location south of Doson peninsula is the most suitable location, both in the cost and in the value ranking of the MCE, mainly because of the more favourable hinterland connections.

- From the MCE carried out in chapter 5 it can be concluded that sub-variant 1, a rather narrow pier that stretches out till the deeper part of the sea, is the most suitable option when the ranking of the best value and value/cost ratio are concerned. This sub-variant is more expensive than no. 3, but it is much safer and it answers more of the demands and desires in advance posed. Therefore sub-variant 1 has been worked out in further detail.

- Given the tidal and wave data that were available during this study, the most optimal design for the access channel is a one-way channel in which a tidal window of +1.40 m CD will be in effect. The accompanying lengths are 1401 m for the container quay and 678 m for the general cargo quay.

- The existing hinterland connections (both inland waterways, road- and railway network) are not sufficient. Not only the connection to Haiphong should be constructed, but larger improvements for the further hinterland are necessary as well.

- The costs for this project have been estimated at $ 410 mln. This only includes the construction costs of the components. Maintenance costs, costs for machinery, water- and power supplies, navigational aids, harbour equipment and transportation at the terminal have not been taken into account.

Final conclusion

Going back to the objective of this report, *"Determine the feasibility of a deep-water port in the Haiphong area"*, it can be concluded that it is indeed necessary and technical feasible to build a deep-water port in Haiphong. The economic feasibility however should still be determined.

8.3 Recommendations

Since this study is the first phase of an extensive research, more investigation has to be carried out to design all components. The quays for instance have been dimensioned on their length; only after thorough soil research one will be able to finish the complete design.
The following recommendations will be taken for granted.

- **Data collection**
  - Extensive data collection shall be carried out to collect more adequate data on waves, winds, tides and currents. When adequate data of the last couple of decades on these subjects are not available, use shall be made of computer models.

- **Morphology**
  - Hardly any research has been done on morphology in the specific area around Doson. This shall be done urgently, since the morphology will have a major influence on the exact design of the breakwaters and access channel.
  - The effects of resiltation after (maintenance) dredging shall be studied.
  - Further investigation is required to the influences of the sedimentation process in the River Van Uc. It shall be studied if specific measures are necessary to avoid too much sedimentation in the port basin.

- **Access channel**
  - Further optimisation of the channel is desirable. During this study no accurate data was available. Use of adequate data might have influence on the dimensions of the channel.
  - When more data on the waves are available one shall determine on which conditions the wave window will be based.
  - A real time simulator will give more insight in the functioning of the access channel.
  - Further investigation in the influences of extensive dredging on the fishing habitat is required.

- **Breakwaters**
  - A wave penetration model will give more insight in the exact positioning of the breakwaters. More data on the wave characteristics will be necessary to use the model in a proper way.
  - The construction material in this report assumed, has not been further specified. The possibilities concerning materials of which the breakwaters will be constructed shall be studied more thoroughly. The design of the breakwater will be influenced by the available materials from the quarries in the surroundings of Haiphong as well.

- **Port basin / quays**
  - The length of the quays highly depends on the dimensions of the access channel. Since the construction of the quays will be rather expensive (it is expected that the quays should be founded at a depth of -30/ -40 m CD), it might be more profitable to construct shorter quays and a wider access channel. An accurate analysis can only be done when the quay design has been worked out in more detail.

- **Landfill**
  - The necessary level of the land has not yet been determined. When one will calculate this level, the sea level rise shall be taken into account as well.

- **Hinterland connections**
  - At the national/ regional level, it is not only desirable, but imperative to further investigate in the safety and accessibility of the inland waterways. The expected throughput per inland barge will increase strongly in the next few decades. The present safety of the waterways is completely inadequate.
  - The national railway network is insufficient to handle the expected amount of cargo in a proper manor. The network shall be modernized. It should save enormous amounts of time and money when the entire network in the country would operate at the same type of rail.
  - The load on Highway No. 5 (Haiphong-Hanoi) will rapidly increase in the future. Despite of the recently executed extensions, the capacity of the road will not be sufficient to handle the expected throughput.

- **Costs**
  - A cost-benefit analysis should be carried out to determine if and when the new port will break even. In this study only the costs of the main components have been estimated. Investigations are required on the detailed outline of the costs and the expected returns. The economic feasibility can be determined by means of this cost-benefit analysis.

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Appendix I

Traffic forecast

I.1 GDP growth

The base year will be the last year of which complete (both general cargo and share of containers) traffic throughput figures are available. This is the year 2001.
Total cargo throughput: 8.575.000 tons
Among which containers: 228.000 TEU (1 TEU ≈ 15 tons) → 3.420.000 tons
For the period of 2001-2005 the GDP growth percentage forecasted by the Worldbank is used. They do not give any forecasts on the years after 2005. The forecast of the initial master plan study (presented in table 2.4) shows however that it is expected that the growth of GDP will decrease after 2005.
Hence, for these calculations the following percentages are used:
2001-2005 7%
2006-2010 6.7%
2010-2020 6.5%

This results in the following forecast for the cargo throughput in Haiphong port:

Table I.1: cargo throughput Haiphong port

Type of cargo	General cargo	Among which	
Year	(tons)	Container (tons)	Container (TEU)
2001	8.575.000	3.420.000	228.000
2005	11.240.076	4.482.922	298.861
2010	15.545.022	6.199.880	413.325
2020	29.180.143	11.638.028	775.869

The complete existing port of Haiphong (main city port, Chua Ve terminal, Doan Xa and Vat Cach) was designed for a maximum throughput capacity of 8.500.000 tons. Last year however, this amount was exceeded, by almost 2 mln tons. For these calculations the original maximum throughput capacity of 8.500.000 tons will be used, because the port is functioning more optimal at its maximum design capacity than when it is overloaded.
Throughput capacity deep-water port:
2010 7.045.022 tons
2020 20.680.143 tons

I.2 Import/Export growth figures

The average growth percentages per year for the import, export and domestic cargo throughput for the period 1991-2001 are as follows:
Import 17.7%
Export 10.8%
Domestic 6.5%

If these percentages would be the same for the period 2001-2010, the throughput for 2010 would be:

Table I.2: throughput with high import/export growth percentages

	General cargo	Import	Export	Domestic
	(∑ Im + Ex + Dom)	(tons)	(tons)	(tons)
2001	8.575.000	4.358.000	1.336.000	2.882.000
2005	14.084.757	8.363.597	2.013.564	3.707.596
2010	27.334.133	18.891.890	3.362.515	5.079.728

These results are much higher, especially because of the tremendous growth percentage of import in the last ten years. It seems not realistic to expect the import to keep on growing at the same rate. Therefore another prospect is used, the forecast of the Vietnam National Maritime Bureau.

They expect the im-export volume, going through the marine transport system of Vietnam, to grow from 54 mln tons in 2000 to 112 mln tons in 2010. This means an average annual growth of 7.3% for the import and export. Assumed is that the domestic growth percentage is linked to the GDP growth (7% for 2000-2005 and 6.7% for 2005-2010). This results in the following expectation for the throughput in Haiphong port:

Table I.3: throughput with lower import/ export growth percentages

	Cargo throughput (∑ Im + Ex + Dom)	Import (tons)	Export (tons)	Domestic (tons)
2001	8.575.000	4358000	1336000	2882000
2005	11.325.444	5776784	1770946	3777714
2010	15.959.897	8216460	2518859	5224577

Throughput capacity deep-water port
2010 7.459.897 tons

I.3 Government's throughput expectations whole country

In a master plan for the seaport system of Vietnam, written by the Government[1], the throughput of cargo in all seaports in Vietnam for the year 2010 was expected to be 200 mln tons. Of that amount, the ports in the provinces Quang Ninh to Ninh Binh are expected to handle 54-67 mln tons.

In the next table the ports in this district will be enumerated and their expected capacity listed as well. After subtracting these capacities the remaining cargo for Haiphong port can be calculated.

Table I.4: surrounding ports and their expected capacity

Port	Type of port	Minimum expected capacity in 2010 (tons)	Maximum expected capacity in 2010(tons)
Cai Lan port	General	10.000.000	11.500.000
Cam Pha	Coal	5.000.000	5.200.000
B12	Oil	0	3.500.000
Dinh Vu	General	2.500.000	6.000.000
Dinh Vu Industrial Zone	Industry zone	2.500.000	6.500.000
Others	Cement, a.o.	3.500.000	3.800.000
Total		**23.200.000**	**36.500.000**

This results in a cargo throughput for the port of Haiphong of (extreme) minimum 17.500.000 tons and (extreme) maximum 43.800.000 tons. The average it will be 30.650.000 tons.

This means the following for the deep-water port:
Minimum: 9.000.000 tons
Maximum: 35.300.000 tons
Average: 22.150.000 tons

The Vietnam National Maritime Bureau published a scope[25] for the Haiphong and Cai Lan port for 2010. Their forecast is that the ports will handle 27-29 mln tons by that time. Hence, Haiphong port will handle 15.5-19 mln tons and the deep-water port will handle 7-10.5 mln tons.

Appendix II

Wind data

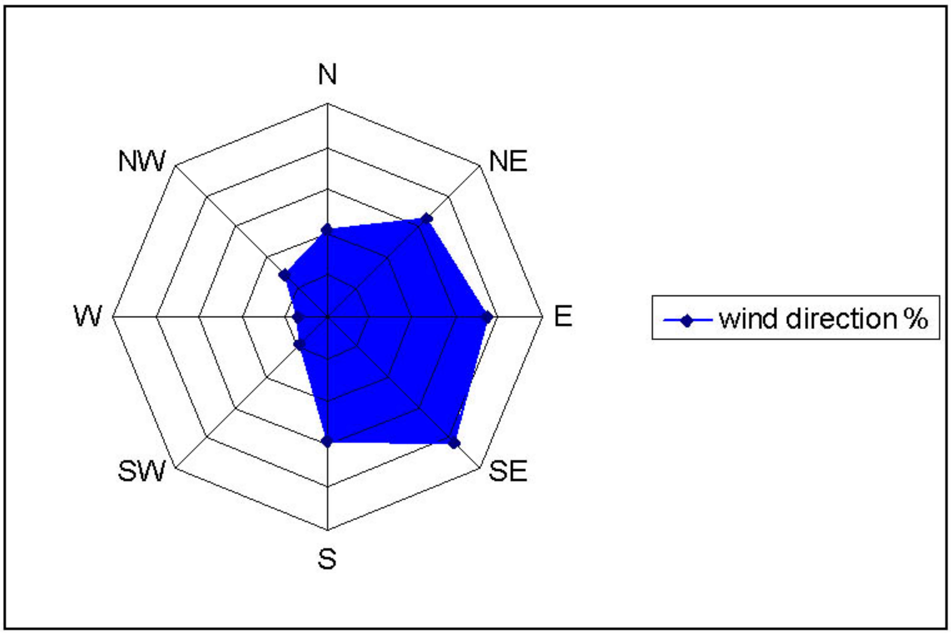


Figure II.1: wind rose, % of occurring per direction

Appendix III

Wave data

The data for area 40 are used; these describe a rather larger area, covering the entire Vietnamese coast and the southern coast of China.

Table III.1: wave direction, height and period

Season	Main direction(s) (% of all directions)	Wave height	Wave period
December-February	NE (56%) N (20%) E (14%)	1-2 m (28%) 2-3 m (26%) max.: 9-10 m	6-7 s (31%) 7-8 s (26%)
March-May	NE (32%) E (20%) S (14%)	0-1 m (35%) 1-2 m (38%) max.: 7-8 m	4-5 s (27%) 5-6 s (34%)
June-August	S (34%) SW (27%) SE (9%)	0-1 m (39%) 1-2 m (35%) max.: 7-8 m	5-6 s (34%) 6-7 s (26%)
September-November	NE (40%) E (14%) N(13%)	1-2 m (30%) 2-3 m (25%) max.: 9-10 m	6-7 s (30%) 7-8 s (26%)
Annual	NE (33%) S (15%) E (14%)	1-2 m (33%) 2-3 m (24%) max.: 8-9 m	5-6 s (30%) 6-7 s (30%)

The histogram results for the whole year have been compared with the results for June-September.

Table III.2: significant wave height versus probability of exceedance

Sign. wave height (m) versus probability of exceedance (%)		
Prob. of exceedance	Wave height all year	Wave height June-Sept
90.0	0.2	0.4
80.0	0.4	0.5
70.0	0.5	0.6
60.0	0.7	0.7
50.0	0.8	0.8
40.0	0.9	0.9
30.0	1.0	1.0
20.0	1.2	1.2
10.0	1.5	1.5
5.0	1.8	2.1
2.5	2.1	2.3
1.0	2.6	2.9

Table III.3: percentage of occurrence of sign. wave height versus wave direction

Wave direction	N	NE	E	SE	S	SW	W	NW	Total
Wave height									
0.0-0.5	0	0	3.4	1.7	3.4	1.7	0	0	10.2
0.5-1.0	1.7	3.4	8.6	5.1	18.9	12	0	0	49.7
1.0-1.5	0	5.2	3.4	0	6.9	3.4	0	1.7	20.6
1.5-2.0	0	10.3	0	0	0	1.7	0	0	12
2.0-2.5	0	5.2	0	0	0	0	0	0	5.2
2.5-3.0	0	0	0	0	0	0	0	0	0
3.0-3.5	0	0	0	0	0	0	0	0	0
3.5-4.0	0	0	0	1.7	0	0	0	0	1.7
>4.0	0	0	0	0	0	0	0	0	0
Total	1.7	24.1	15.4	8.5	29.2	18.8	0	1.7	99.4

Reference: www.waveclimate.com

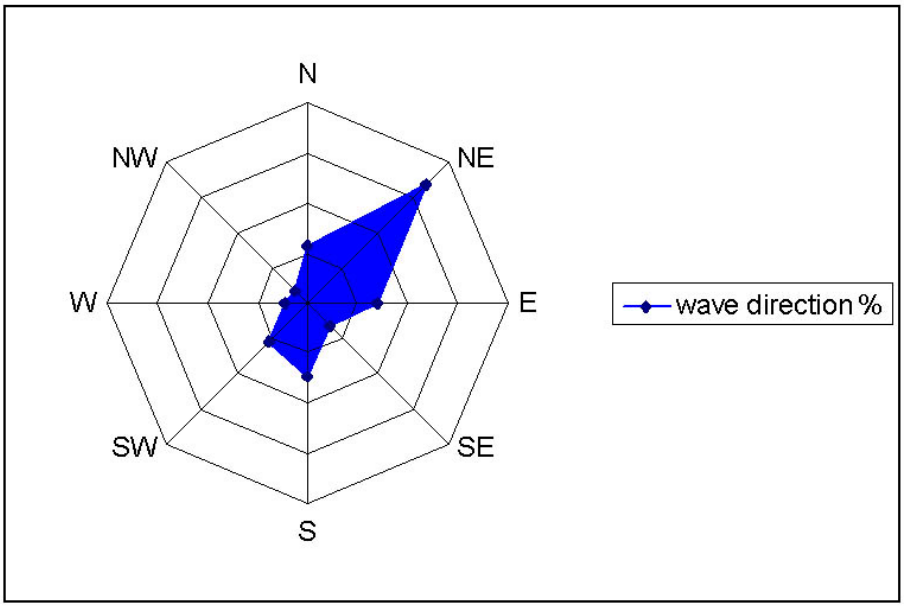


Figure III.1: wave rose, % of occurring per direction

Appendix IV

Sand banks formation

At the mouth of the rivers Lach Huyen and Nam Trieu, many sand banks have been formed by different dynamic forces, mainly waves and tide currents. The main perpetrator of the formation of such sources is the outgoing tide current.

Sandbanks are formed under water at 300-500 meters from the shore, because waves crash into the shore. The strong outgoing current erodes bottom sediments, including fine and medium sands and takes these materials to the sea. The erosion phenomenon of the seashore in this area occurs mainly in summer. In general, the current mechanism in the region is as follows: waves crashing into Cat Hai create wave current speeds of 0.12-0.68 m/s; the waves are divided into 2 branches: one flows to Nam Trieu estuary and the other flows to Lach Huyen estuary. These sub reflux currents meet the river currents outgoing from Nam Trieu and Lach Huyen. Those currents press and annul each other, thus creating favourable conditions for sedimentation and formation of under water sandbanks along Nam Trieu estuary from Hoang Chau commune up to No 12 light buoy. In summer, the alluvium volume is quite large at a total amount of 3.560 mln m^3. The under water bank over 2 kilometres of Dinh Vu will receive a quite large amount of sediment of 6-11 cm/month. In particular the section 4-5 km away from the estuary receives the largest amount of sediment.

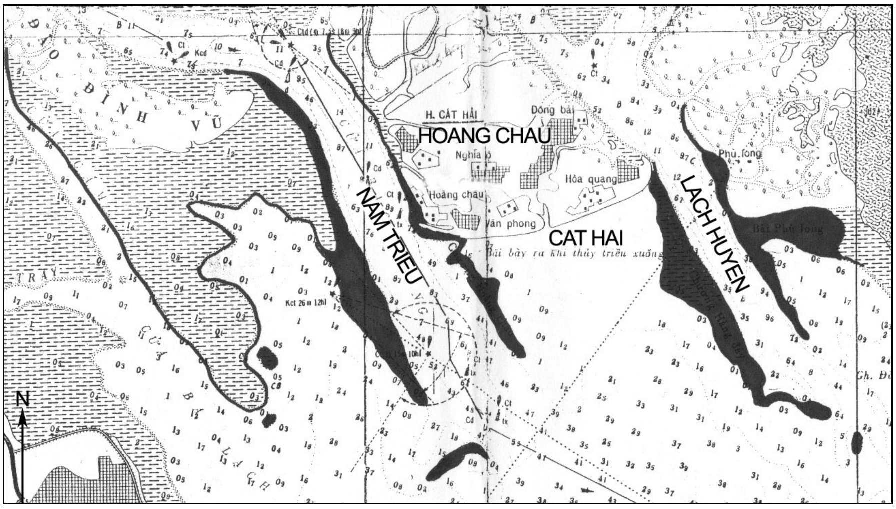


Figure IV.1: sand banks near Cat Hai

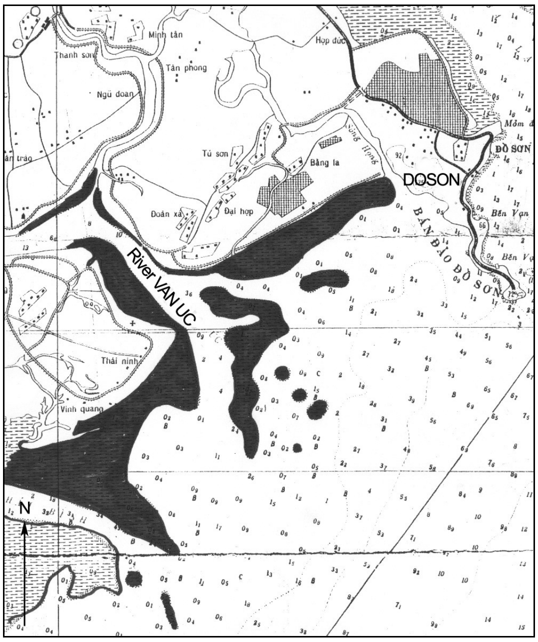


Figure IV.2: sand banks near Doson

Appendix V

Container terminal, required areas

The following formula can be used to calculate the required regular storage area per type of container.

$$O = \frac{C_i * \overline{t_d} * F}{r * 365 * m_i}$$

In which:

O	=	*area required*	*[m²]*
C_i	=	*number of container movements per year per type of stack*	*[TEU]*
t_d	=	*average dwell time*	*[days]*
F	=	*required area per TEU inclusive of equipment travelling lanes*	*[m²]*
r	=	*average stacking height/ nominal stacking height (0.6-0.9)*	*[-]*
m_i	=	*acceptable average occupancy rate (0.65-0.70)*	*[-]*

For import through the regular storage counts:

C_i = *658.000 TEU*
t_d = *(T+2)/3, T=18 days, t_d = 6.67 days*
F = *Gantry crane (RMG/ RTG), nominal stacking height of 3, F = 13 m^2/TEU*
r = *0.75*
m_i = *0.65*

Surface area requirements for the import container stacks:

$$O = \frac{658.000 * 6.67 * 13}{0.75 * 365 * 0.65} = 320.487 \quad m^2$$

For export through the regular storage the factors F, r and m_i stay the same. For C_i and t_d the following can be taken:

C_i = *122.200 TEU*
t_d = *(T+2)/3, T=15 days, t_d = 5.67 days*

Surface area requirements for the export container stacks:

$$O = \frac{122.200 * 5.67 * 13}{0.75 * 365 * 0.65} = 50.591 \quad m^2$$

For domestic transport through the regular storage the factors F, r and m_i stay the same. For C_i and t_d the following can be taken into account:

C_i = *239.700 TEU*
t_d = *(T+2)/3, T=15 days, t_d = 5.67 days*

Surface area requirements for the domestic container stacks:

$$O = \frac{239.700 * 5.67 * 13}{0.75 * 365 * 0.65} = 99.237 \quad m^2$$

Empty containers are usually stored outside the terminal area. The storage factors r and m_i stay the same. For C_i, t_d and F the following can be taken into account:

C_i = *908.667 TEU*
t_d = *(T+2)/3, T=25 days, t_d = 9 days*
F = *Gantry crane (RMG/ RTG), nominal stacking height of 5, F = 8 m^2/TEU*

Surface area requirements for the empty container stacks:

$$O = \frac{908.667 * 9 * 8}{0.75 * 365 * 0.65} = 367.680 \quad m^2$$

For reefers through the regular storage the factors *F*, *r,* t_d and m_i stay the same. For C_i the following can be taken into account:

C_i = *54.833 TEU*

Surface area requirements for the reefer stacks:

$$O = \frac{54.833 * 7 * 13}{0.75 * 365 * 0.65} = 28.042 \quad m^2$$

For the calculation of the required surface area for the Container Freight Station the following formula is used:

$$O_{CFS} = \frac{C_i * V * t_d * f_1 * f_2}{h_a * m_i * 365}$$

In which:

C_i	=	*number of TEU moved through CFS*	*[TEU/yr]*
V	=	*contents of 1 TEU container (=29 m^3)*	*[m^3]*
t_d	=	*dwell time*	*[days]*
f_1	=	*gross area / net area*	*[-]*
f_2	=	*bulking factor*	*[-]*
h_a	=	*average height of cargo in the CFS*	*[m]*
m_i	=	*acceptable occupancy rate*	*[-]*

For import, export and domestic transport the following values are used:

V	=	*29 m^3*
f_1	=	*1.4*
f_2	=	*1.2*
h_a	=	*height of 1 container 2.44 m*
m_i	=	*0.65*

Import	C_i = 383.833 TEU	t_d = 7 days
Export	C_i = 65.800 TEU	t_d = 6 days
Domestic	C_i = 42.300 TEU	t_d = 6 days.

The required surface area O_{CFS} then is:

Import	226.127 m^2
Export	32.227 m^2
Domestic	21.360 m^2
Total	**279.714 m^2**

Appendix VI

General Cargo terminal, required areas

The required area can be calculated with the following formula:

$$O = \frac{f_1 * f_2 * C_{ts} * \overline{t_d}}{m_{ts} * h * \rho * 365}$$

In which:

O	=	*area required for the transit shed/ open storage*	*[m²]*
C_{ts}	=	*fraction of total annual throughput C_s which passes the transit shed*	*[-]*
t_d	=	*average dwell time of the cargo*	*[days]*
ρ	=	*average relative density of the cargo as stowed in the ship, e.g. 0.6*	*[-]*
h	=	*average stacking height in the storage, e.g. 2 m*	*[m]*
f_1	=	*proportion gross/net surface in connection with traffic lanes for FLT's, e.g. 1.5*	*[-]*
f_2	=	*bulking factor due to stripping and separately stacking of special consignments, damaged goods, etc., e.g. 1.2*	*[-]*
m_{ts}	=	*average rate of occupation of the transit shed or storage, e.g. 0.70*	*[-]*

This results in the following formula:

$$O = \frac{1.5 * 1.2 * C_{ts} * t_d}{0.70 * 2 * 0.6 * 365}$$

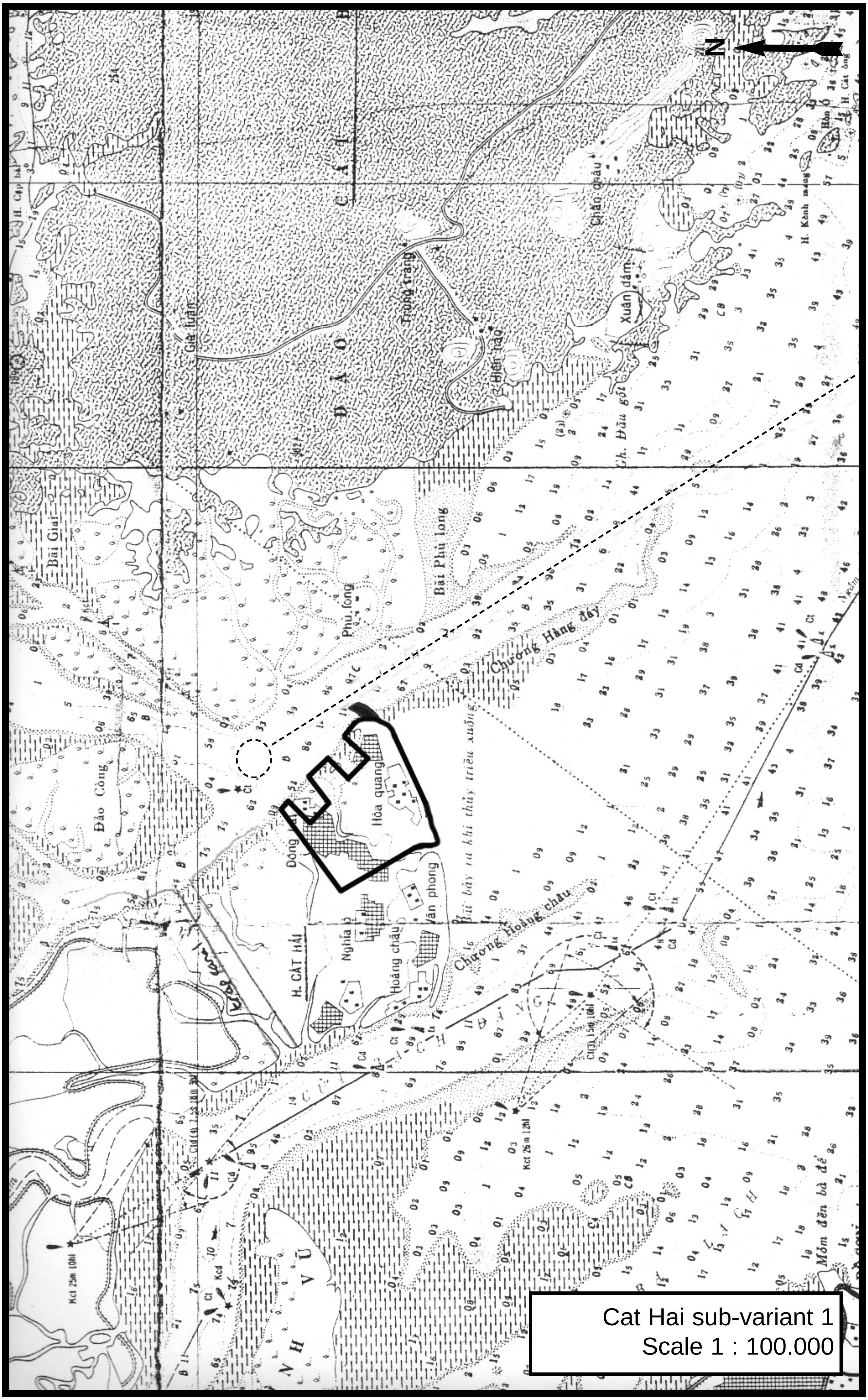
The factors dwell time (t_d) and fraction of annual throughout (C_{ts}) differ for both types of storage.

Transit shed	t_d = 8 days	C_{ts} = 900.000 ton/yr	required area → 42.270 m^2
Open storage	t_d = 10 days	C_{ts} = 600.000 ton/yr	required area → 35.225 m^2

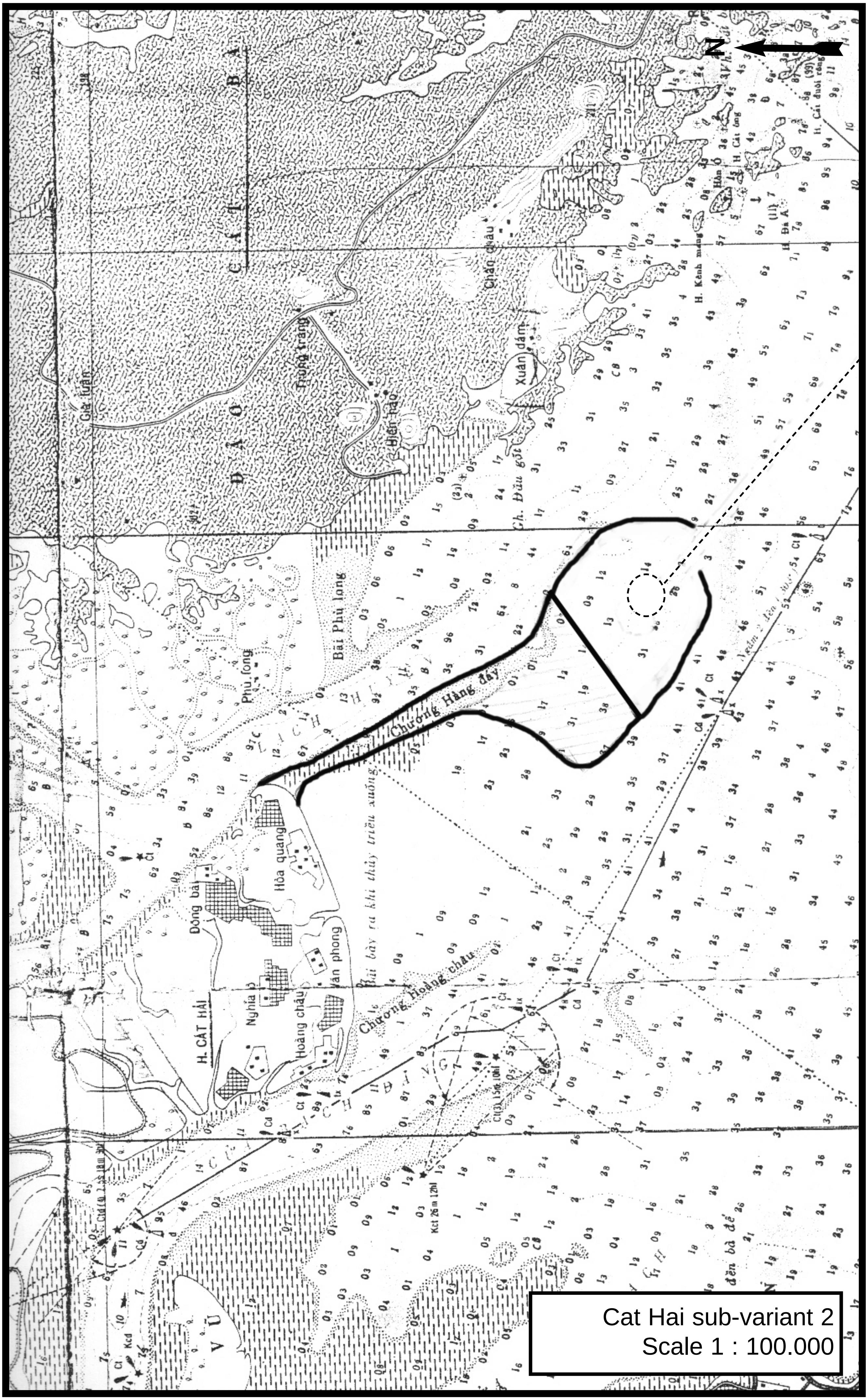
Appendix VII

Maps of different (sub-)variants

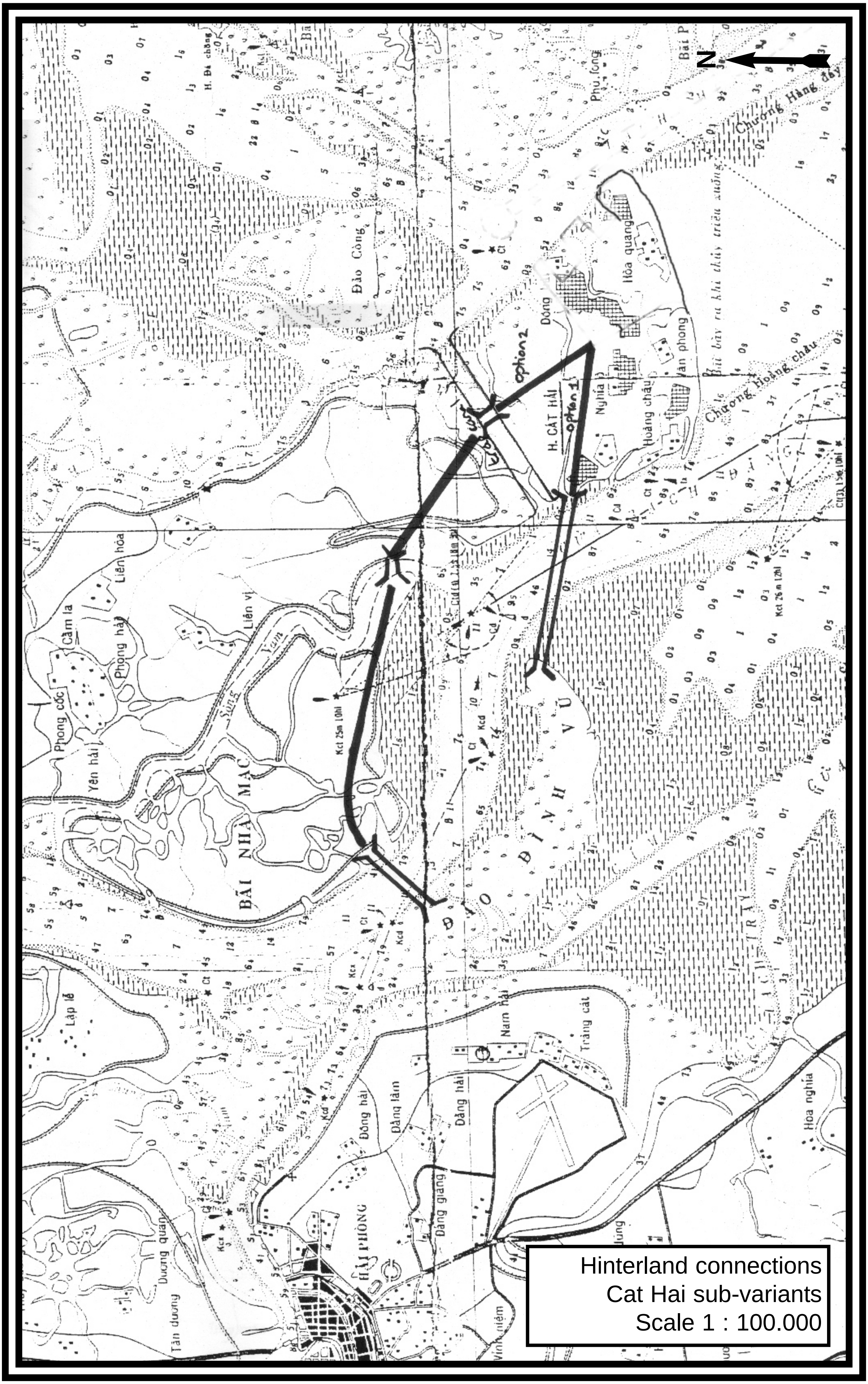
Map 1: Cat Hai, sub-variant 1
Map 2: Cat Hai, sub-variant 2
Map 3: hinterland connection Cat Hai
Map 4: southwards of Doson, sub-variant 1
Map 5: southwards of Doson, sub-variant 2



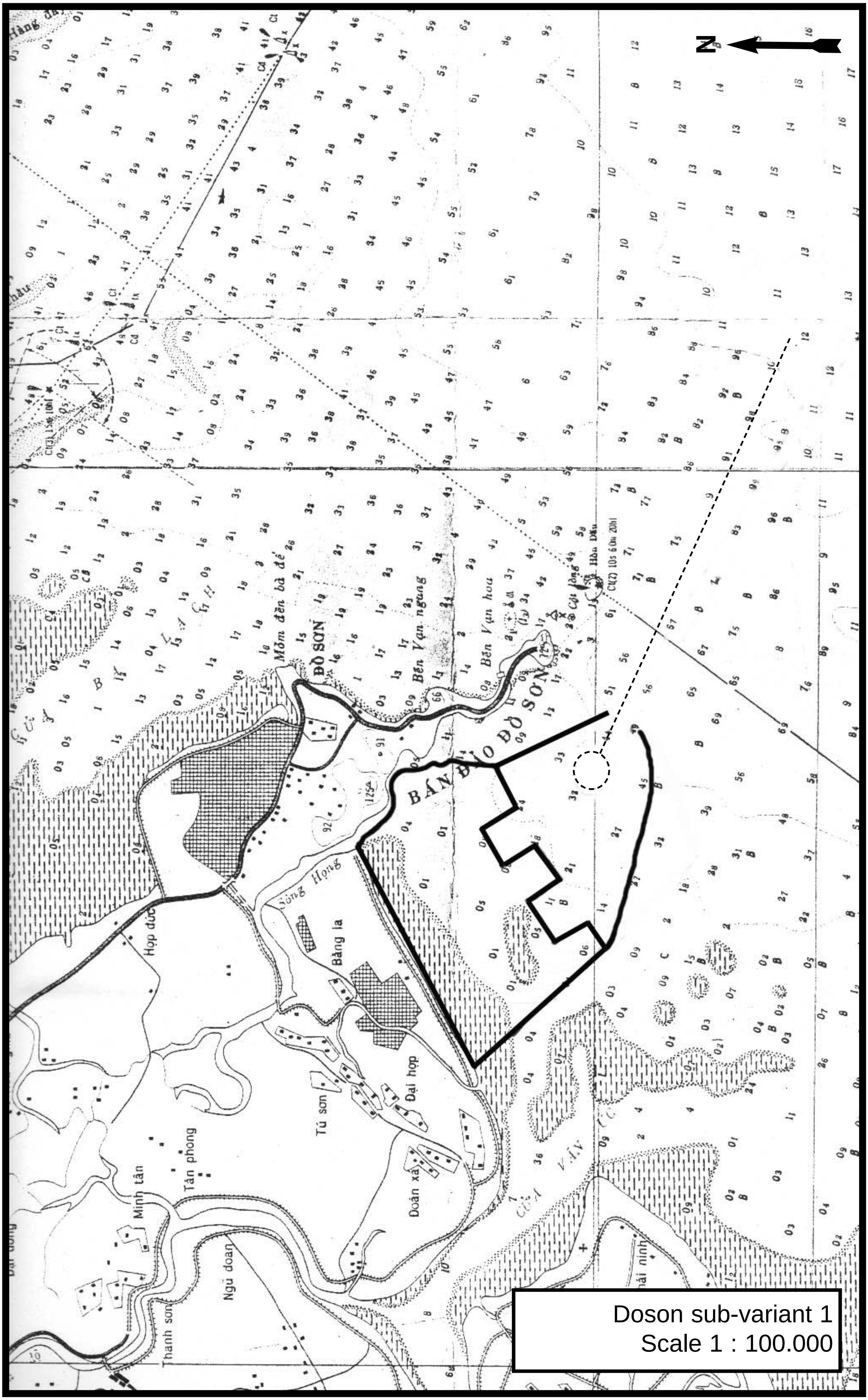
Cat Hai sub-variant 1
Scale 1 : 100.000



Cat Hai sub-variant 2
Scale 1 : 100.000



Hinterland connections
Cat Hai sub-variants
Scale 1 : 100.000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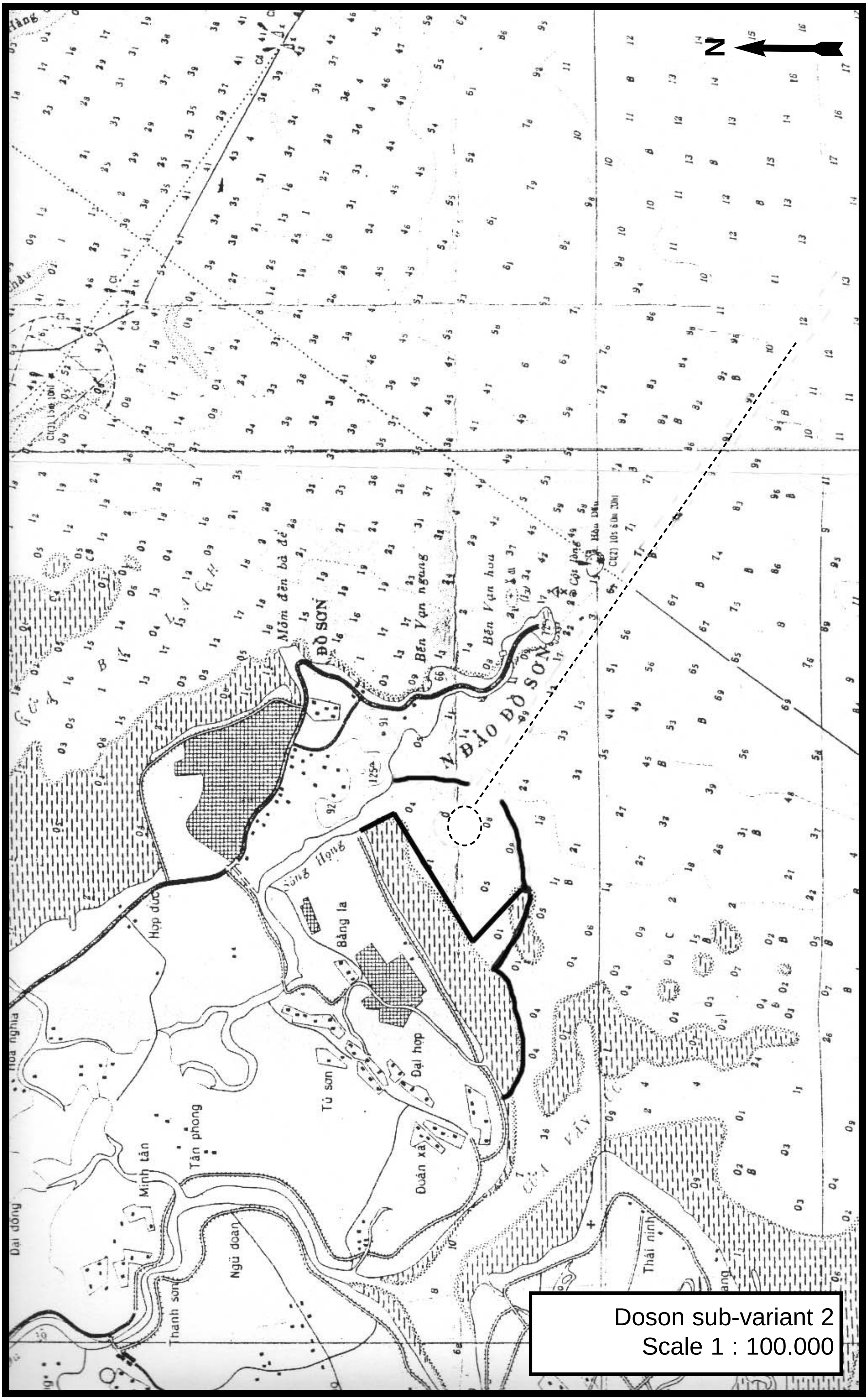
ĐỒ SƠN
Bàng la
Hợp đức
Đại hợp
Tú sơn
Tân phong
Minh tân
Đoàn xá
Ngũ đoan
Thanh sơn
Doson sub-variant 1
Scale 1 : 100.000



Doson sub-variant 2
Scale 1 : 100.000

Appendix VIII

Sensitivity analysis MCE chapter 3

Weighting factors all the same

Table VIII.1: scores with same weighting factors

Main criterion	**Sub-criterion**	**WF**	**Cat Hai**		**Southwards of Doson**	
			Score * WF		Score * WF	
			Sub-var. 1	Sub-var. 2	Sub-var. 1	Sub-var. 2
Functionality						
	Accessible	91	273	637	637	819
	Reachable (port)	91	455	273	637	637
	Reachable (hinterland conn.)	91	273	91	819	819
	Extendible	91	455	273	819	637
Construction						
	Construction in phases	91	637	91	455	637
	Reachable (site)	91	273	91	637	819
Environment						
	Quiet (minor nuisance)	91	91	819	637	455
	Employability	91	455	637	637	455
	Space-using	91	91	819	637	819
Experience						
	Prestigious	91	637	819	637	455
Sustainability						
	Minor maintenance	91	455	273	637	819
TOTAL		1000	**4095**	**4823**	**7189**	**7371**

Weighting factors from the port authority's point of view

Table VIII.2: mutual weights

		A	B	C	D	E	F	G	H	I	J	K	**Σ**
Functionality													
Accessible	A		1	1	1	1	1	1	1	1	1	1	**10**
Reachable (port)	B	0		1	1	1	1	1	1	1	1	1	**9**
Reachable (hinterland connections)	C	0	0		1	1	1	1	1	1	1	1	**8**
Extendible	D	0	0	0		0	1	1	0	1	0	0	**3**
Construction													
Construction in phases	E	0	0	0	1		1	1	1	1	1	1	**7**
Reachable (site)	F	0	0	0	0	0		1	0	1	0	0	**2**
Environment													
Quiet (minor nuisance)	G	0	0	0	0	0	0		0	0	0	0	**0**
Employability	H	0	0	0	1	0	1	1		1	0	0	**4**
Space-using	I	0	0	0	0	0	0	1	0		0	0	**1**
Environment													
Prestigious	J	0	0	0	1	0	1	1	1	1		0	**5**
Sustainability													
Minor maintenance	K	0	0	0	1	0	1	1	1	1	1		**6**

Table VIII.3: weighting factor

		Score Σ	Weighting factor
	Functionality		
A	Accessible	20	180
B	Reachable (port)	18	163
C	Reachable (hinterland connection)	16	144
D	Extendible	6	63
	Construction		
E	Construction in phases	14	126
F	Reachable (site)	4	45
	Environment		
G	Quiet (minor nuisance)	1	9
H	Employability	8	72
I	Space-using	2	18
	Experience		
J	Prestigious	10	90
	Sustainability		
K	Minor maintenance	12	108
		Σ=111	1000

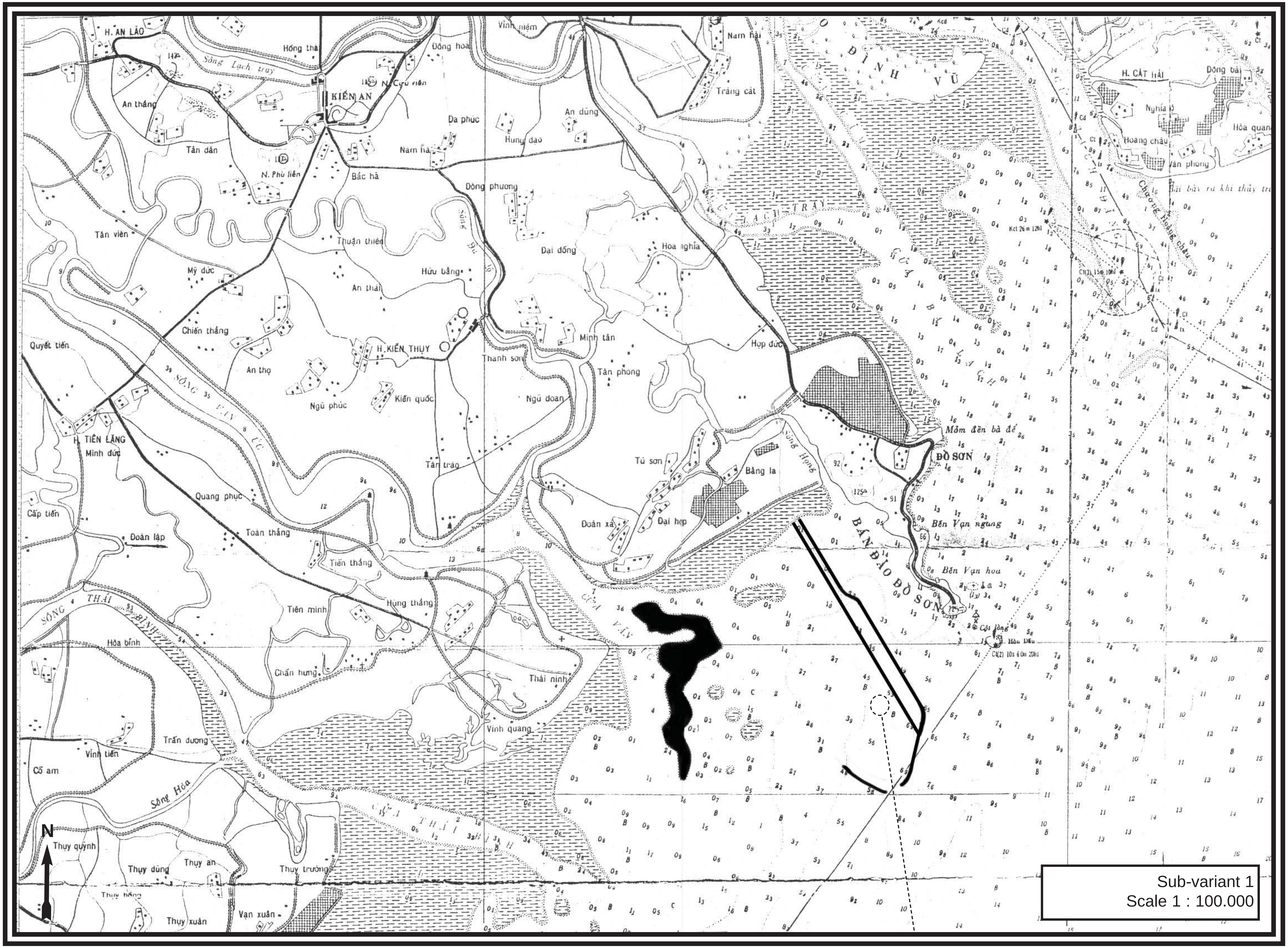
Table VIII.4: scores with port authority's weighting factors

Main criterion	**Sub-criterion**	**WF**	**Cat Hai**		**Southwards of Doson**	
			Score * WF		Score * WF	
			Sub-var. 1	Sub-var. 2	Sub-var. 1	Sub-var. 2
Functionality						
	Accessible	180	540	1260	1260	1620
	Reachable (port)	163	815	489	1141	1141
	Reachable (hinterland conn.)	144	432	144	1296	1296
	Extendible	63	315	189	567	441
Construction						
	Construction in phases	126	882	126	630	882
	Reachable (site)	45	135	45	315	405
Environment						
	Quiet (minor nuisance)	9	9	81	63	45
	Employability	72	360	504	504	360
	Space-using	18	18	162	126	162
Experience						
	Prestigious	91	637	819	637	455
Sustainability						
	Minor maintenance	108	540	324	756	972
TOTAL		1000	**4683**	**4143**	**7295**	**7779**

Appendix IX

Maps of different layouts

Map 1: sub-variant 1
Map 2: sub-variant 2
Map 3: sub-variant 3
Map 4: sub-variant 4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Hồng thái
Đồng hoà
Vĩnh niệm
Nam hải
Sông Lạch tray
KIẾN AN
N. Cứu viên
Trang cát
An thắng
Đa phúc
An dũng
Tân dân
Hưng đạo
Nam hà
N. Phù liễn
Bắc hà
Đông phương
Tân viên
Thuận thiên
Đại đồng
Hoa nghĩa
Mỹ đức
Hữu bằng
An thái
ĐÌNH VŨ
H. CÁT HẢI
Đồng bài
Nghĩa lộ
Hoàng châu
Hòa quang
Văn phong
Chiến thắng
Quyết tiến
H. KIẾN THỤY
Thanh sơn
Minh tân
Tân phong
Hợp đức
An thọ
Ngũ phúc
Kiến quốc
Ngũ đoan
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H. TIÊN LÃNG
Minh đức
Tân trào
Tú sơn
Bằng la
Sông Hồng
Mỏm đền bà đế
ĐỒ SƠN
Quang phục
Cấp tiến
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Đại hợp
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Toàn thắng
Đoàn lập
Tiên thắng
BÁN ĐẢO ĐỒ SƠN
Bến Vạn hoa
Hùng thắng
Tiên minh
SÔNG THÁI BÌNH
Hòa bình
Chấn hưng
Thái ninh
Vinh quang
Trấn dương
Vinh tiến
Cổ am
Sông Hóa
CỬA THÁI BÌNH
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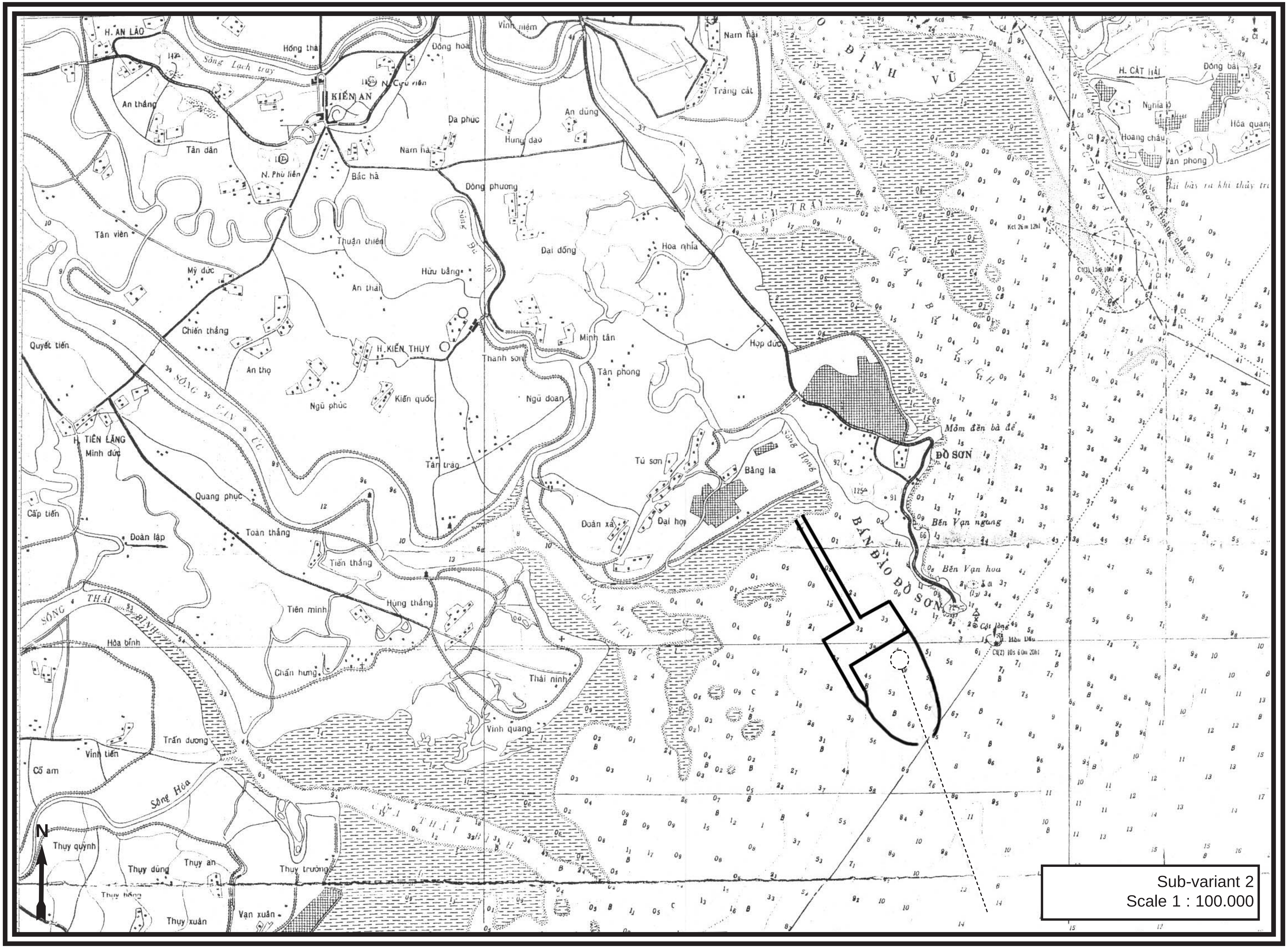
Thụy dũng
Thụy an
Thụy trường
Thụy hồng
Thụy xuân
Vạn xuân
Sub-variant 1
Scale 1 : 100.000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Đồng hoà
Vĩnh niệm
Nam hải
Tràng cát
ĐÌNH VŨ
H. CÁT HẢI
Đông bài
Nghĩa lộ
Hoàng châu
Hòa quang
Văn phong
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Thụy quỳnh
Thụy dũng
Thụy an
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Thụy hồng
Thụy xuân
Vạn xuân
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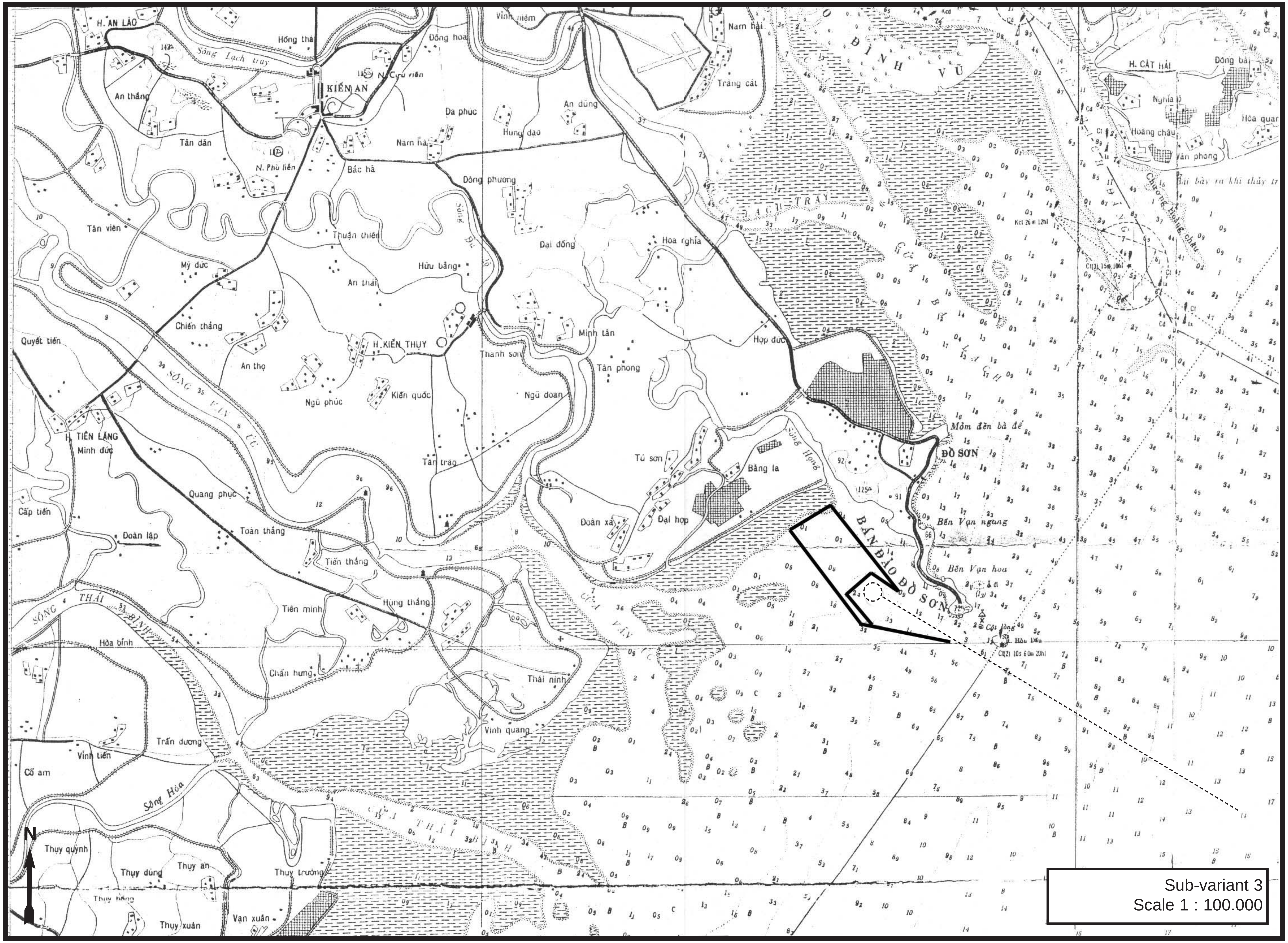
Sub-variant 2
Scale 1 : 100.000



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Sông Lạch tray
KIẾN AN
N. Cựu viên
Đồng hoà
Vĩnh niệm
Nam hải
ĐÌNH VŨ
Tràng cát
H. CÁT HẢI
Đồng bài
Nghĩa lộ
Hoà quang
Hoàng châu
Văn phong
An thắng
Tân dân
N. Phù liễn
Bắc hà
Nam hà
Đa phúc
An dũng
Hưng đạo
Đông phương
Tân viên
Mỹ đức
Thuận thiên
Hữu bằng
An thái
Đại đồng
Hoa nghĩa
Chiến thắng
Quyết tiến
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Thanh sơn
Minh tân
Hợp đức
Tân phong
An thọ
Ngũ phúc
Kiến quốc
Ngũ đoan
SÔNG VĂN ÚC
H. TIÊN LÃNG
Minh đức
Tân trào
Tú sơn
Bằng la
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Mõm đền bà đế
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Tiên minh
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Hoà bình
Chấn hưng
Thái ninh
Vinh quang
Trấn dương
Vinh tiến
Cổ am
Sông Hóa
CỬA THÁI BÌNH
Thụy quỳnh
Thụy dũng
Thụy an
Thụy trường
Thụy hồng
Thụy xuân
Vạn xuân
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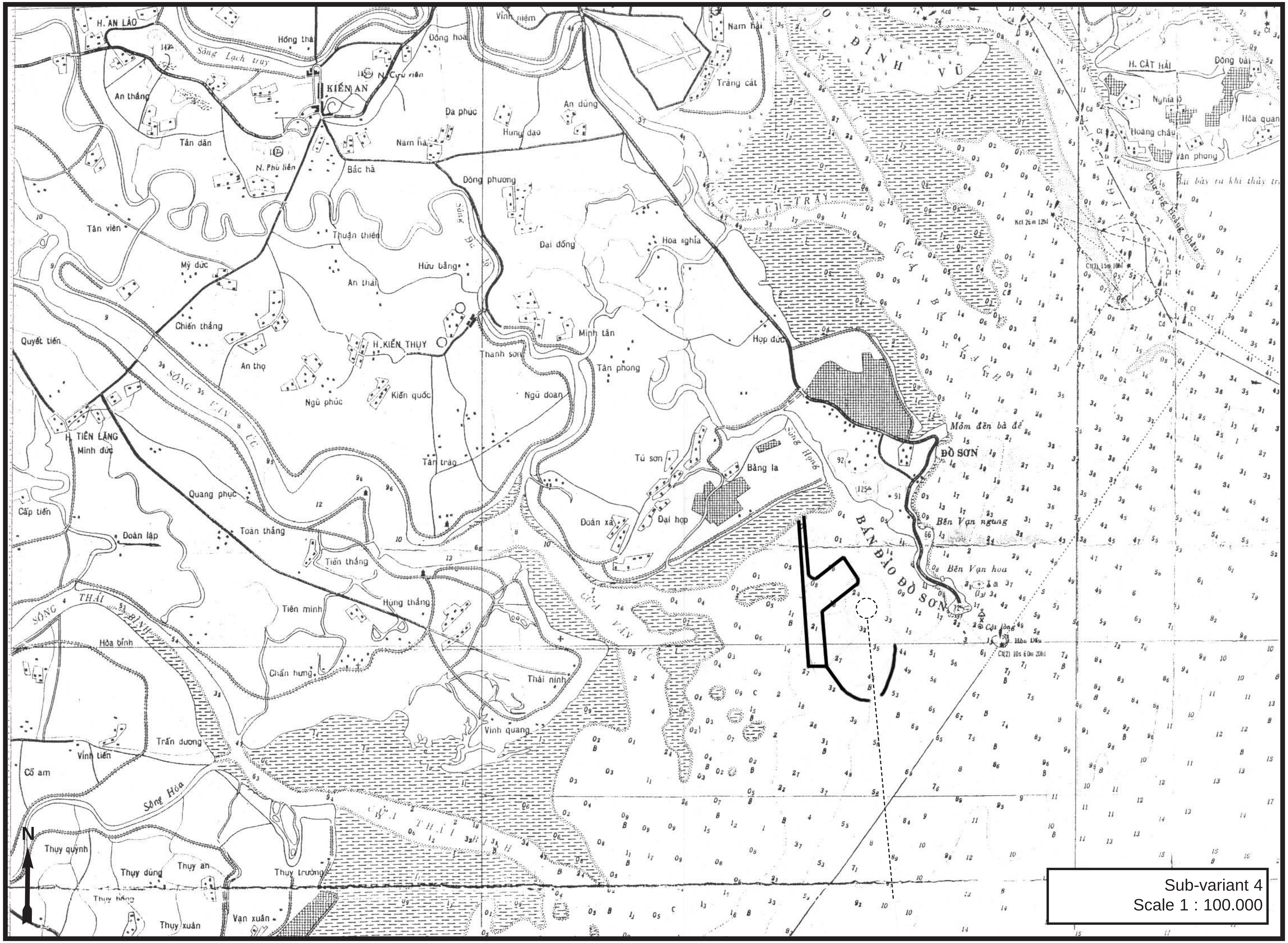
Sub-variant 3
Scale 1 : 100.000



Sub-variant 4
Scale 1 : 100.000

Appendix X

Breakwaters

Chapter 3		Costs in $							
Cat Hai 1									
Length	**Depth**	**Height**	**Width**	**m3**	**ton**			**Total tonnage**	
		(D+4.5							
(m)	*(m)*	*m)*	*(2,5*H+2)*	*(W*H)*	*(m3/1,6)*				
500	11	15,5	40,75	631,625	394,77			197382,81	
		4,5	13,25	59,625	37,266			0	
		4,5	13,25	59,625	37,266			0	
Toe	**Depth**	**Height**	**Length**	**m3**	**ton**	**m3**	**m3**		
		(D+4.5							
	(m)	*m)*	*(2,5*H)*	*cone+core*	*(m3/1,6)*	*cone*	*core*		
	11	15,5	38,75	12659	7911,9	12058	601	7911,8736	
								205294,69	total tons
	Cone	0,5*0,33*,014*L*L*H				$16/ton		3284715	total costs
	Core	0,5*L*H*2							

Cat Hai 2									
Length	**Depth**	**Height**	**Width**	**m3**	**ton**			**Total tonnage**	
		(D+4.5							
(m)	*(m)*	*m)*	*(2,5*H+2)*	*(W*H)*	*(m3/1,6)*				
3000	4,1	8,6	23,5	202,1	126,31			378937,5	
2500	3	7,5	20,75	155,625	97,266			243164,06	
1000	1,2	5,7	16,25	92,625	57,891			57890,625	
Toe	**Depth**	**Height**	**Length**	**m3**	**ton**	**m3**	**m3**		
		(D+4.5							
	(m)	*m)*	*(2,5*H)*	*cone+core*	*(m3/1,6)*	*cone*	*core*		
	3	7,5	18,75	1506,709	941,69	1366	141	941,69312	
	3	7,5	18,75	1506,709	941,69	1366	141	941,69312	
								681875,57	total tons
	Cone	0,5*0,33*,014*L*L*H				$16/ton		10910009	total costs
	Core	0,5*L*H*2							

Doson 1								
Length	**Depth**	**Height**	**Width**	**m3**	**ton**			**Total tonnage**
		(D+4.5						
(m)	*(m)*	*m)*	*(2,5*H+2)*	*(W*H)*	*(m3/1,6)*			
1000	1,4	5,9	16,75	98,825	61,766			61765,625
1000	2,7	7,2	20	144	90			90000
1000	3,2	7,7	21,25	163,625	102,27			102265,63
1000	4,5	9	24,5	220,5	137,81			137812,5
Toe	**Depth**	**Height**	**Length**	**m3**	**ton**	**m3**	**m3**	
		(D+4.5						
	(m)	*m)*	*(2,5*H)*	*cone+core*	*(m3/1,6)*	*cone*	*core*	
	4,5	9	22,5	2563,093	1601,9	2361	203	1601,9332

								393445,68	total tons
	Cone	0,5*0,33*,014*L*L*H				$16/ton		6295130,9	total costs
	Core	0,5*L*H*2							

Doson 2

Length	Depth	Height	Width	m3	ton			Total tonnage	
(m)	*(m)*	*(D+4.5 m)*	*(2,5*H+2)*	*(W*H)*	*(m3/1,6)*				
1000	1,1	5,6	16	89,6	56			56000	
500	1,8	6,3	17,75	111,825	69,891			34945,313	
500	2,4	6,9	19,25	132,825	83,016			41507,813	
Toe	**Depth**	**Height**	**Length**	**m3**	**ton**	**m3**	**m3**		
	(m)	*(D+4.5 m)*	*(2,5*H)*	*cone+core*	*(m3/1,6)*	*cone*	*core*		
	2,4	6,9	17,25	1182,778	739,24	1064	119	739,23638	
								133192,36	total tons
	Cone	0,5*0,33*,014*L*L*H				$16/ton		2131077,8	total costs
	Core	0,5*L*H*2							

Chapter 5

Sub-variant 1

Length	Depth	Height	Width	m3	ton			Total tonnage	
(m)	*(m)*	*(D+4.5 m)*	*(2,5*H+2)*	*(W*H)*	*(m3/1,6)*				
1000	4,9	9,4	25,5	239,7	149,81			149812,5	
600	5,8	10,3	27,75	285,825	178,64			107184,38	
1600	6,9	11,4	30,5	347,7	217,31			347700	
Toe	**Depth**	**Height**	**Length**	**m3**	**ton**	**m3**	**m3**		
	(m)	*(D+4.5 m)*	*(2,5*H)*	*cone+core*	*(m3/1,6)*	*cone*	*core*		
	4,9	9,4	23,5	2910,435	1819	2690	221	1819,0218	
	5,8	10,3	25,75	3803,612	2377,3	3538	265	2377,2573	
	6,9	11,4	28,5	5122,325	3201,5	4797	325	3201,4529	
								612094,61	total tons
	Cone	0,5*0,33*,014*L*L*H				$16/ton		51223,247	total costs
	Core	0,5*L*H*2							

Sub-variant 2

Length	Depth	Height	Width	m3	ton			Total tonnage	
(m)	*(m)*	*(D+4.5 m)*	*(2,5*H+2)*	*(W*H)*	*(m3/1,6)*				
1000	5,1	9,6	26	249,6	156			156000	
2000	5,6	10,1	27,25	275,225	172,02			344031,25	
1000	6,9	11,4	30,5	347,7	217,31			217312,5	
1400	6,5	11	29,5	324,5	202,81			283937,5	

Toe	Depth	Height	Length	m3	ton	m3	m3		
		(D+4.5							
	(m)	*m)*	*(2,5*H)*	*cone+core*	*(m3/1,6)*	*cone*	*core*		
	6,5	11	27,5	4612,444	2882,8	4310	303	2882,7777	
	6,9	11,4	28,5	5122,325	3201,5	4797	325	3201,4529	
								1007365,5	total tons
	Cone	0,5*0,33*,014*L*L*H				$16/ton		16117848	total costs
	Core	0,5*L*H*2							

Sub-variant 3

Length	Depth	Height	Width	m3	ton	Total tonnage
		(D+4.5				
(m)	*(m)*	*m)*	*(2,5*H+2)*	*(W*H)*	*(m3/1,6)*	
700	3,3	7,8	21,5	167,7	104,81	73368,75
900	1,5	6	17	102	63,75	57375
700	5,1	9,6	26	249,6	156	109200

Toe	Depth	Height	Length	m3	ton	m3	m3		
		(D+4.5							
	(m)	*m)*	*(2,5*H)*	*cone+core*	*(m3/1,6)*	*cone*	*core*		
	5,1	9,6	24	3095,286	1934,6	2865	230	1934,5536	
								241878,3	total tons
	Cone	0,5*0,33*,014*L*L*H				$16/ton		3870052,9	total costs
	Core	0,5*L*H*2							

Sub-variant 4

Length	Depth	Height	Width	m3	ton	Total tonnage
		(D+4.5				
(m)	*(m)*	*m)*	*(2,5*H+2)*	*(W*H)*	*(m3/1,6)*	
1000	4,9	9,4	25,5	239,7	149,81	149812,5
1000	3,2	7,7	21,25	163,625	102,27	102265,63
700	3,9	8,4	23	193,2	120,75	84525
500	5,3	9,8	26,5	259,7	162,31	81156,25

Toe	Depth	Height	Length	m3	ton	m3	m3		
		(D+4.5							
	(m)	*m)*	*(2,5*H)*	*cone+core*	*(m3/1,6)*	*cone*	*core*		
	4,9	9,4	23,5	2910,435	1819	2690	221	1819,0218	
	5,3	9,8	24,5	3287,797	2054,9	3048	240	2054,8733	
	3,9	8,4	21	2095,65	1309,8	1919	176	1309,781	
								422943,05	total tons
	Cone	0,5*0,33*,014*L*L*H				$16/ton		6767088,8	total costs
	Core	0,5*L*H*2							

Appendix XI

Sensitivity analysis MCE chapter 5

Weighting factors all the same

Table XI.1: scores with same weighting factors

Main criterion	Sub-criterion	WF	Score * WF			
			Sub-var. 1	Sub-var. 2	Sub-var. 3	Sub-var. 4
Functionality						
	Accessible	91	819	455	91	637
	Safe	91	637	273	91	819
	User friendly	91	637	637	455	819
	Extendible	91	819	455	91	455
	Re-arrangable	91	819	637	455	637
Construction						
	Construction in phases	91	273	273	637	637
	Reachable (site)	91	637	455	273	455
Environment						
	Quiet (minor nuisance)	91	819	637	273	455
	Space-using	91	819	637	273	637
Experience						
	Prestigious	91	819	637	273	637
Sustainability						
	Minor maintenance	91	637	455	91	273
TOTAL		**1000**	**7735**	**5551**	**3003**	**6461**

Weighting factors from the port authority's point of view

Table XI.2: mutual weights

		A	B	C	D	E	F	G	H	I	J	K	Σ
Functionality													
Accessible	A		1	1	1	1	1	1	1	1	1	1	**10**
Safe	B	0		1	1	1	1	1	1	1	1	1	**9**
User friendly	C	0	0		1	0	0	1	1	0	1	1	**5**
Extendible	D	0	0	0		0	0	1	1	0	0	1	**3**
Re-arrangable	E	0	0	1	1		0	1	1	1	1	1	**7**
Construction													
Construction in phases	F	0	0	1	1	1		1	1	1	1	1	**8**
Reachable (site)	G	0	0	0	0	0	0		1	0	0	0	**1**
Environment													
Quiet (minor nuisance)	H	0	0	0	0	0	0	0		0	0	0	**0**
Space-using	I	0	0	1	1	0	0	1	1		1	1	**6**
Environment													
Prestigious	J	0	0	0	1	0	0	1	1	0		1	**4**
Sustainability													
Minor maintenance	K	0	0	0	0	0	0	1	1	0	0		**2**

Table XI.3: weighting factor

		Score Σ	Weighting factor
	Functionality		
A	Accessible	20	180
B	Safe	18	162
C	User friendly	10	90
D	Extendible	6	55
E	Re-arrangable	14	126
	Construction		
F	Construction in phases	16	144
G	Reachable (site)	2	18
	Environment		
H	Quiet (minor nuisance)	1	9
I	Space-using	12	108
	Experience		
J	Prestigious	8	72
	Sustainability		
K	Minor maintenance	4	36
		Σ=111	**1000**

Table XI.4: scores with port authority's weighting factors

Main criterion	Sub-criterion	WF	Score * WF			
			Sub-var. 1	Sub-var. 2	Sub-var. 3	Sub-var. 4
Functionality						
	Accessible	180	1620	900	180	1260
	Safe	162	1134	486	162	1458
	User friendly	90	630	630	450	810
	Extendible	55	495	275	55	275
	Re-arrangable	126	1134	882	630	882
Construction						
	Construction in phases	144	432	432	1008	1008
	Reachable (site)	18	126	90	54	90
Environment						
	Quiet (minor nuisance)	9	81	63	27	45
	Space-using	108	972	756	324	756
Experience						
	Prestigious	72	648	504	216	704
Sustainability						
	Minor maintenance	36	252	180	36	108
TOTAL		1000	**7524**	**5198**	**3142**	**7396**

Appendix XII

Simulation results

BASE RUN (10 years)

Site conditions

Tidal window	0
Sections on	0
Con. quay length	1260
GC quay length	603

Mean waiting time (minutes)

Run	1	2	3	4	5	6	7	8	9	10	Total	Mean	Serv.time	% W
Cont.	30	14	21	10	30	20	26	21	27	24	223	44,6	1951,71	2,29
GC	55	1406	766	1091	1303	737	856	1722	1231	691	9858	1972	9280,6	21,2

RUN 1

Site conditions

Tidal window	1,1
Sections on	0
Con. quay length	1260
GC quay length	603

Mean waiting time (minutes)

Run	1	2	3	4	5	6	7	8	9	10	Total	Mean	Serv.time	% W
Cont.	59	41	44	33	61	41	53	49	52	52	485	97	1951,71	4,97
GC	71	1446	816	1120	1355	766	892	1743	1263	707	10179	2036	9280,6	21,9

RUN 2

Site conditions

Tidal window	1,2
Sections on	0
Con. quay length	1260
GC quay length	603

Mean waiting time (minutes)

Run	1	2	3	4	5	6	7	8	9	10	Total	Mean	Serv.time	% W
Cont.	69	56	54	48	74	50	68	63	69	69	620	124	1951,71	6,35
GC	73	1454	846	1140	1395	773	898	1762	1275	727	10343	2069	9280,6	22,3

RUN 3

Site conditions

Tidal window	1,3
Sections on	0
Con. quay length	1260
GC quay length	603

Mean waiting time (minutes)

Run	1	2	3	4	5	6	7	8	9	10	Total	Mean	Serv.time	% W
Cont.	93	84	79	68	93	70	91	86	91	88	843	168,6	1951,71	8,64
GC	103	1466	879	1174	1421	822	931	1790	1309	744	10639	2128	9280,6	22,9

RUN 4

Site conditions

Tidal window	1,4
Sections on	0
Con. quay length	1260
GC quay length	603

Mean waiting time (minutes)

Run	1	2	3	4	5	6	7	8	9	10	Total	Mean	Serv.time	W %
Cont.	128	114	103	97	118	98	115	107	119	119	1118	223,6	1951,71	**11,5**
GC	146	1514	907	1206	1444	866	964	1828	1331	777	10983	2197	9280,6	23,7

RUN 5

Site conditions

Tidal window	1,4
Sections on	0
Con. quay length	1401
GC quay length	678

Mean waiting time (minutes)

Run	1	2	3	4	5	6	7	8	9	10	Total	Mean	Serv.time	W %
Cont.	105	99	90	90	101	80	100	97	105	101	968	193,6	1951,71	**9,92**
GC	105	952	554	612	702	383	780	915	718	254	5975	1195	9280,6	**12,9**

RUN 6

Site conditions

Tidal window	1,4
Sections on	1, 2, 3, 7
Con. quay length	1401
GC quay length	678

Mean waiting time (minutes)

Run	1	2	3	4	5	6	7	8	9	10	Total	Mean	Serv.time	W %
Cont.	84	81	71	73	85	62	81	77	84	83	781	156,2	1951,71	8
GC	83	894	529	551	673	356	726	881	669	235	5597	1119	9280,6	12,1

RUN 7

Site conditions

Tidal window	1,4
Sections on	section 1
Con. quay length	1401
GC quay length	678

Mean waiting time (minutes)

Run	1	2	3	4	5	6	7	8	9	10	Total	Mean	Serv.time	W %
Cont.	85	82	72	74	86	62	81	78	85	84	789	157,8	1951,71	8,09
GC	83	899	531	557	677	358	737	886	674	238	5640	1128	9280,6	12,2

RUN 8

Site conditions

Tidal window	1,5
Sections on	section 1
Con. quay length	1401
GC quay length	678

Mean waiting time (minutes)

Run	1	2	3	4	5	6	7	8	9	10	Total	Mean	Serv.time	W %
Cont.	109	108	94	103	112	85	98	105	110	101	1025	205	1951,71	**10,5**
GC	108	921	571	579	697	374	767	908	719	271	5915	1183	9280,6	12,7

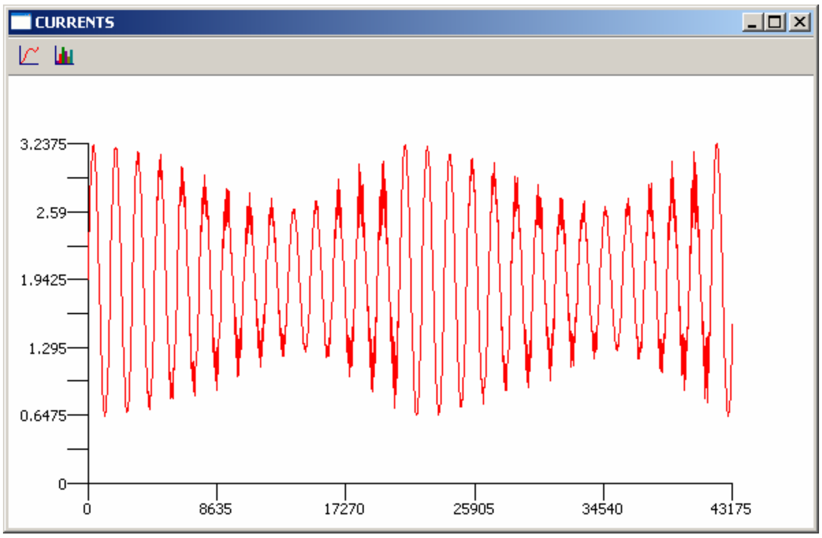


Figure XII.1: tide during 1 month

The y-axis represents the height of the tide compared to CD in m.
The x-axis represents the time in minutes.

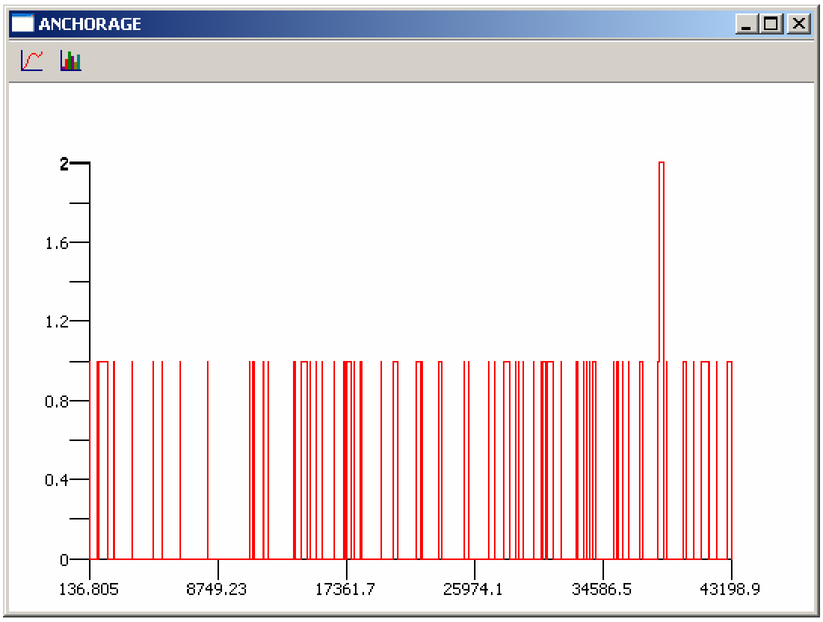


Figure XII.2: number of vessels at the anchorage

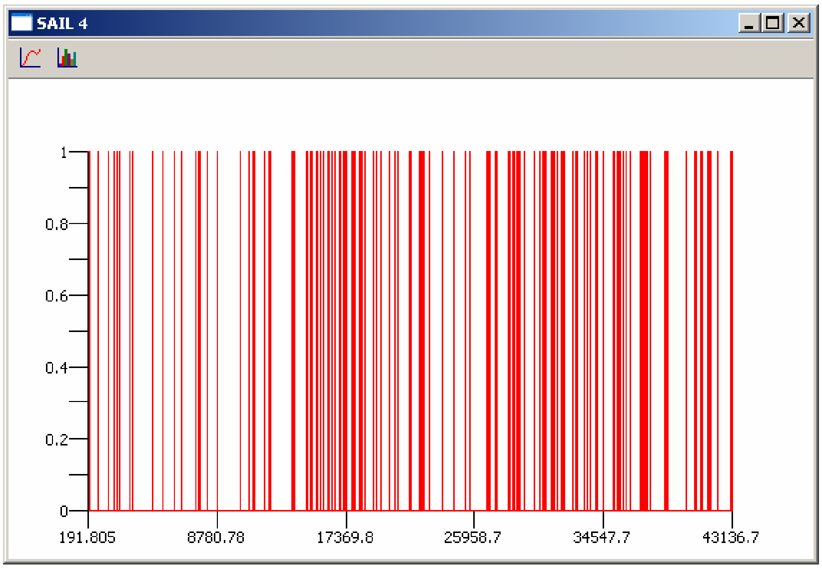


Figure XII.3: number of vessels in turning basin 4

As can be seen from above figure, only one vessel is in the turning basin at the same time.

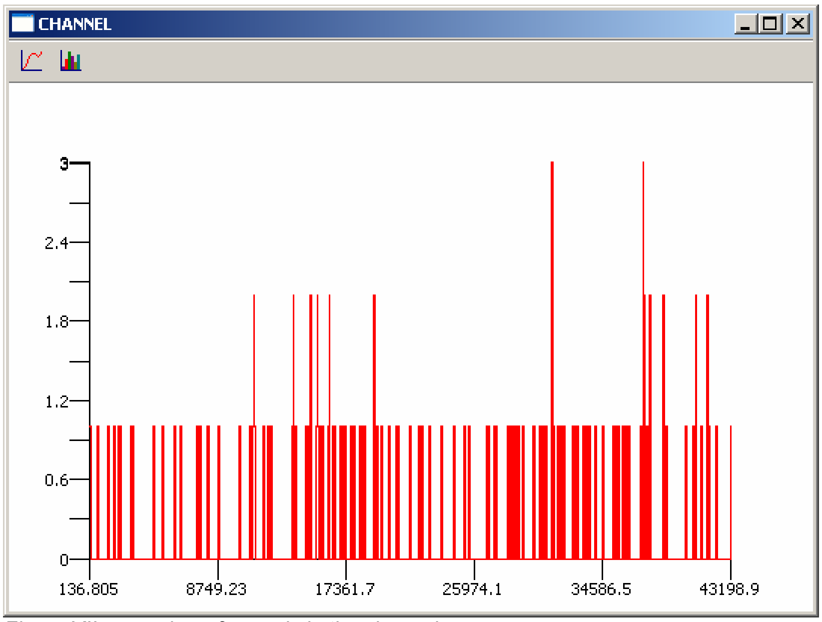
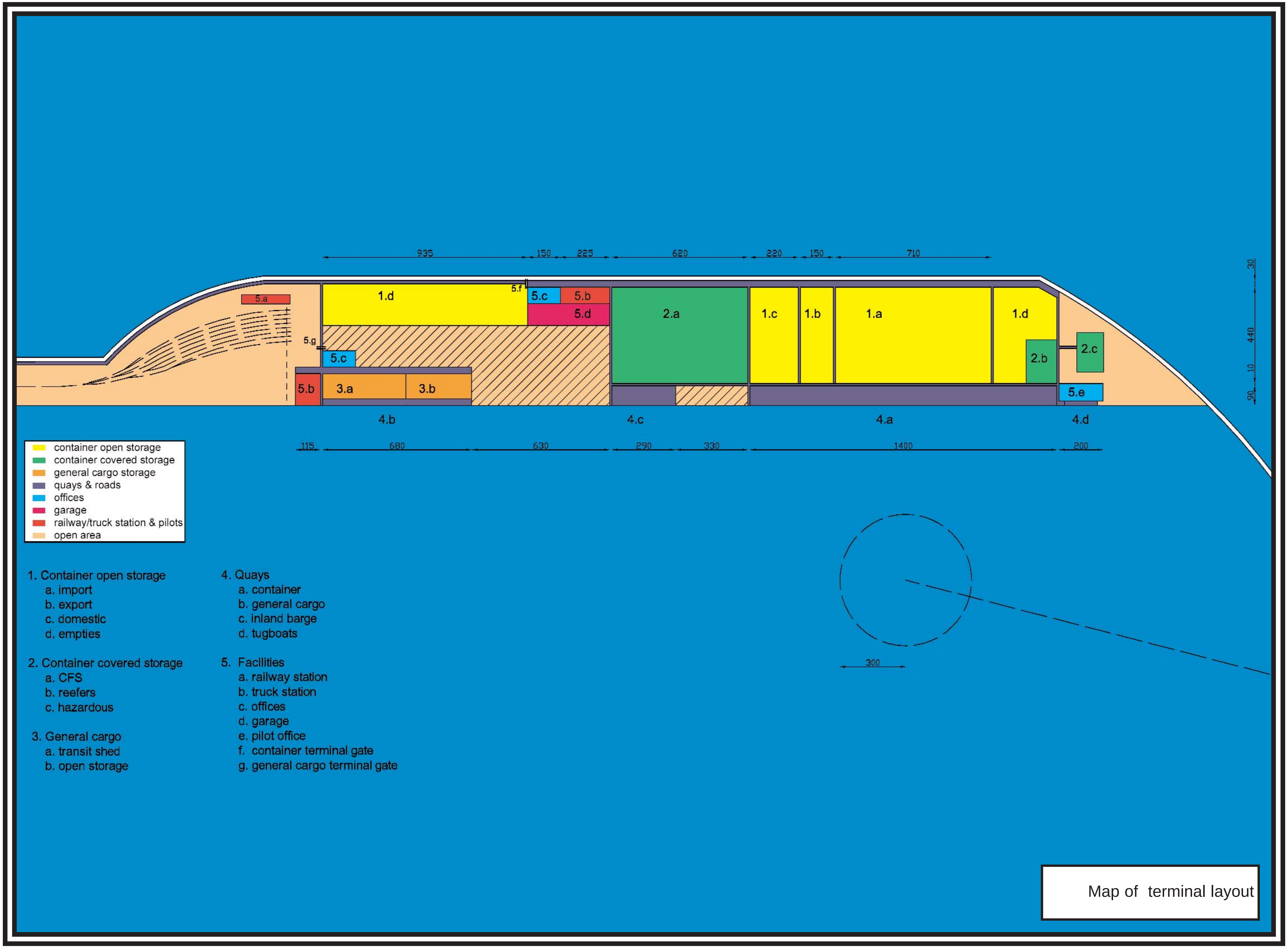


Figure XII.4: number of vessels in the channel

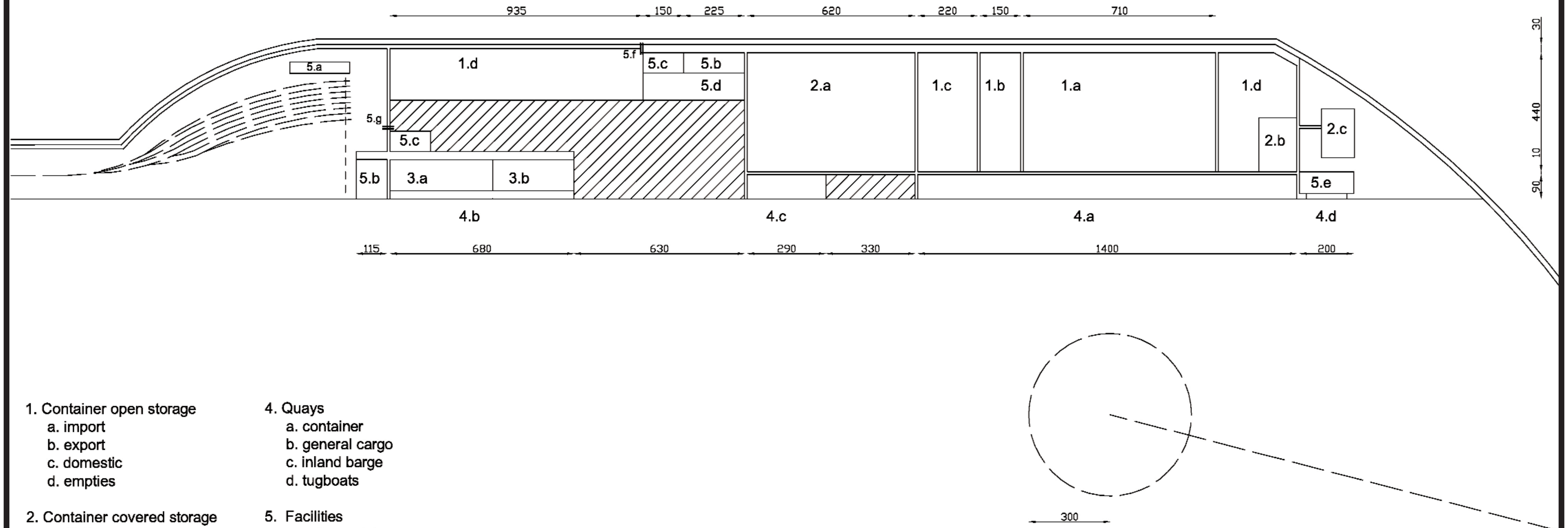
Appendix XIII

Terminal layout

Map 1: terminal layout, coloured map
Map 2: detailed AutoCAD drawing
Map 3: 3D map



935
150
225
620
220
150
710
30
440
10
90
5.a
1.d
5.f
5.c
5.b
5.d
2.a
1.c
1.b
1.a
1.d
2.c
2.b
5.e
5.g
5.c
5.b
3.a
3.b
4.b
4.c
4.a
4.d
115
680
630
290
330
1400
200
300
container open storage
container covered storage
general cargo storage
quays & roads
offices
garage
railway/truck station & pilots
open area
1. Container open storage
a. import
b. export
c. domestic
d. empties
2. Container covered storage
a. CFS
b. reefers
c. hazardous
3. General cargo
a. transit shed
b. open storage
4. Quays
a. container
b. general cargo
c. inland barge
d. tugboats
5. Facilities
a. railway station
b. truck station
c. offices
d. garage
e. pilot office
f. container terminal gate
g. general cargo terminal gate
Map of terminal layout



1. Container open storage
    a. import
    b. export
    c. domestic
    d. empties

2. Container covered storage
    a. CFS
    b. reefers
    c. hazardous

3. General cargo
    a. transit shed
    b. open storage

4. Quays
    a. container
    b. general cargo
    c. inland barge
    d. tugboats

5. Facilities
    a. railway station
    b. truck station
    c. offices
    d. garage
    e. pilot office
    f. container terminal gate
    g. general cargo terminal gate

Terminal layout AutoCAD

3D visualisation

Appendix XIV

Bar chart of construction planning 2004-2010

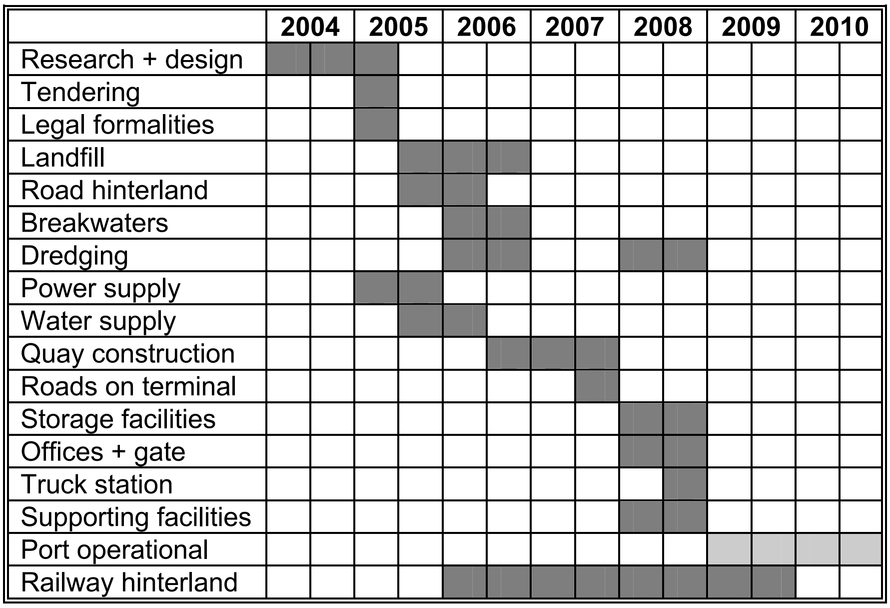
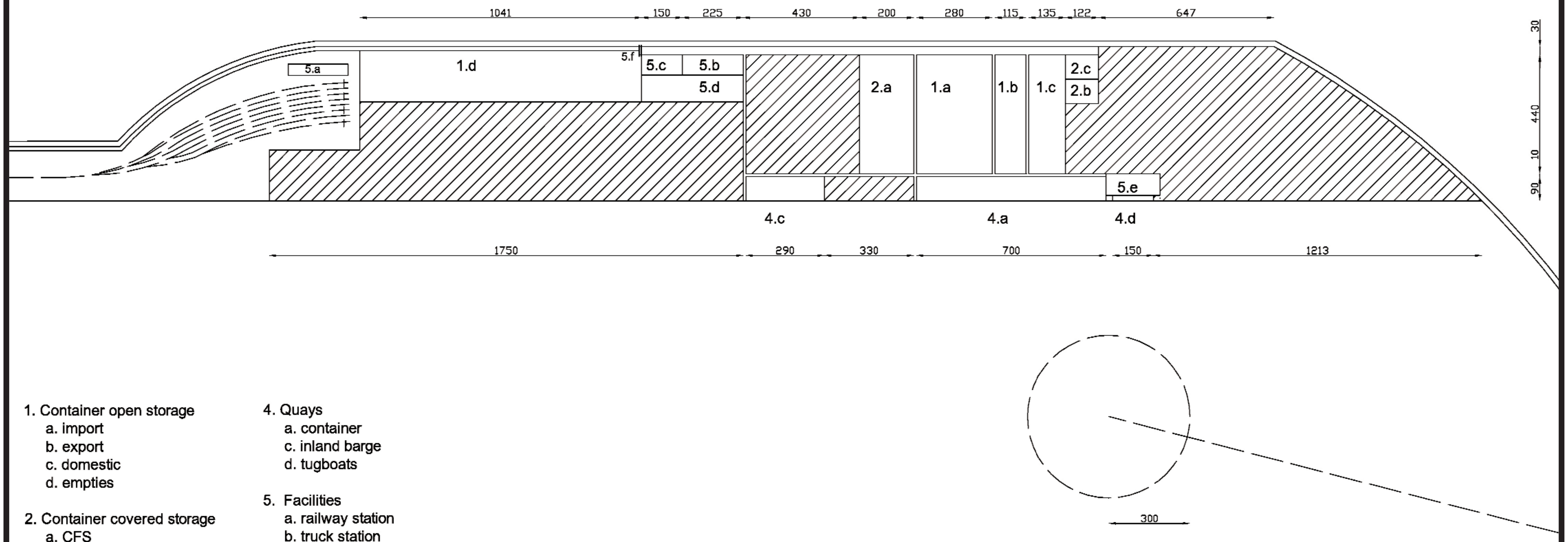


Figure XIV.1: bar chart of construction planning

Construction first phase 2004-2010



1. Container open storage
   a. import
   b. export
   c. domestic
   d. empties

2. Container covered storage
   a. CFS
   b. reefers
   c. hazardous

4. Quays
   a. container
   c. inland barge
   d. tugboats

5. Facilities
   a. railway station
   b. truck station
   c. offices
   d. garage
   e. pilot office
   f. container terminal gate

Map of first phase, 2010

Appendix XV

Cost estimation

Wet infrastructure

- Dredging
- Breakwaters (constructed out of different stone layers, for the calculation of the amount of tonnage, see Appendix X)
- Navigational aids

Port basin

- Container quays
- General cargo quays
- Inland barge quays

It is expected from small research in nearby ports that the quays have to be constructed at a foundation of at least 30-40 meters.

Container terminal

- Apron area (floor (sand/ cement stabilisation, bricks and drainage, 40 cm thick), 4 ship-to-shore gantry cranes per berth)
- Multi Trailer System, for the transport from quay to storage yard
- Storage areas (open areas, asphalt (5 cm) thick)
- CFS (covered storage area)
- Hazardous cargo area (covered area, protected against explosion danger, safety measurements, impenetrable floor)
- Reefers (covered area with special machinery)
- Rubber Tyred Gantry (RTG) or Rail Mounted Gantry (RMG) for transport within the stacks
- Straddle Carriers for transport of containers from the stack to the truck/ railway station

General cargo terminal

- Apron area (floor (sand/ cement stabilisation, bricks and drainage, 40 cm thick), 2 mobile cranes on pneumatic tires per berth)
- Forklift trucks for the transport from quay to transit shed/ open storage (12 FLT's per berth)
- Transit shed (covered area)
- Open storage GC (asphalt, 5 cm)

Hinterland connection

- Truck station (asphalt parking area, small office, petrol station, garage)
- Railway station (small office, classification yard, garage)
- Roads (asphalt, 10 cm thick)
- Rail (double track, foundation for sand embankment, vertical drainage, soft soil improvement)
- Inland waterway (shortcut connection to inland rivers, extra dredging might be desirable)

General facilities

- Landfill
- Offices (customs, port authority, public facilities etc)
- Gate and fence
- Towing, pilot and oarsmen services (quays and offices)
- Harbour equipment (tractors and trailers for long distance transport)
- Roads at the terminal (asphalt, 10 cm thick)
- Garages

Facilities outside the gate

- Water supply
- Power supply