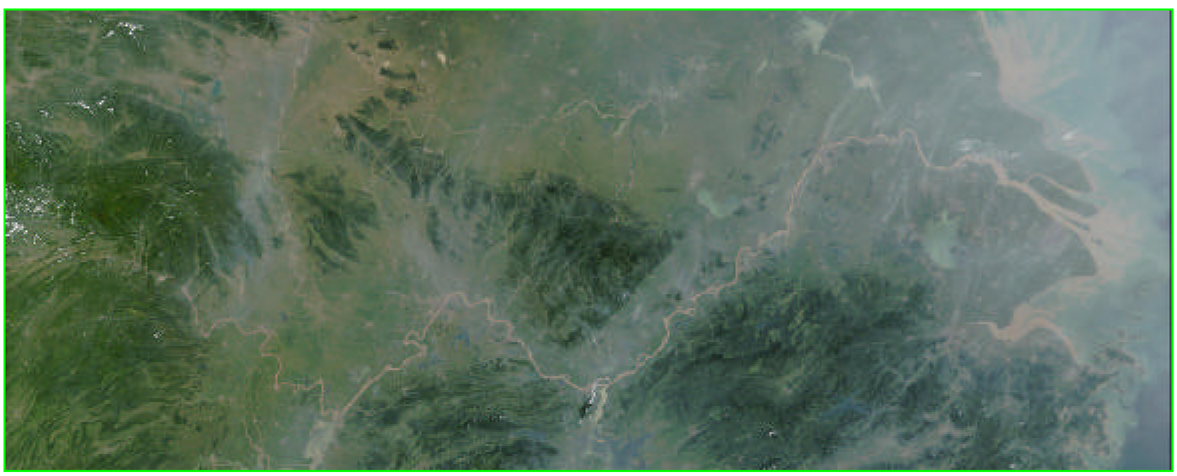
CONTAINER TRANSPORT IN CHINA

An investigation into the suitability of the Yangtze River for container transport from Shanghai Port and Yangshan port



Graduation Committee

Prof Ir. H. Ligteringen
Ir. R. Groenveld
Ir. S. Dekker
Ir. H. Oostinga
Ir. J. Reedijk

Preface

This report is the Master thesis of Attie Kuiken, student at Delft University of Technology, Faculty of Civil Engineering and Geosciences. This thesis project is the last part of my studies in Civil Engineering, specialisation Hydraulic Engineering. The project has been carried out under guidance of Ballast Ham Dredging and Delta Marine Consultants. The subject of this report is to investigate the suitability of the Yangtze River for container transport from Shanghai port and Yangshan Port.

I would like to thank the members of my graduation committee for their comments and support during my graduation project. The members of this committee are:

Prof. Ir. H. Ligteringen (DUT)
Ir. R. Groenveld (DUT)
Ir. S. Dekker (DUT)
Ir. H. Oostinga (BHD)
Ir. J. Reedijk (DMC)

Furthermore I would like to thank Peter de Langen (Erasmus University of Rotterdam), Harrie de Leijer (NEA) and Tarique Arsiwalla for their help and the advices they gave me, and my family and friends for their support during the years I spent in Delft and especially during the months I spent on my thesis.

Attie Kuiken

Summary

To determine to what extend waterway transport can be used in the future, it is necessary to determine the expected throughput. The Chinese economy is undergoing a strong growth. This is strengthened even further by the Chinese membership to the WTO and the attractiveness for foreign investors caused by the low labour costs and the world wide continuing globalisation. The Chinese share to the world total container throughput is increasing every year. In 2001 this share was 9.3%, for 2002 a share of 13% is expected.

As a result, the main container port of China, Shanghai Port, is facing annual throughput growth of about 28%. This is much higher than the 8.6% worldwide growth. With its throughput of 8.61 mTEU in 2002 Shanghai is ranked in the top five of world container ports. To be able to maintain this position a sustained growth is required. The capacity of Shanghai is expected to be stretched to its maximum in 2003. Also the limited channel depth of 9m is a limiting factor for the development of the port. Of the initiated dredging programme the first phase for the channel is realised while the second phase (dredging to 10m below CD) has not started yet even though it was planned to start in 2001.

The capacity problem and the lack of deep-water berths can be solved by the construction of a new deep-water port. The Chinese authorities planned to settle this new port with 52 berths and a capacity of 20 mTEU in 2020 at the Yangshan islands, 100 kilometres south of Shanghai and 30 kilometres offshore. A bridge of 32.2 kilometres will connect the port with the mainland. With the construction of phase 1, which consists of 5 berths and a capacity of 2.2 mTEU, the pressure on Shanghai Port can be diminished. Phase 1 is planned to be operational in 2005. When the construction is delayed it could become difficult to maintain the current position compared to the competitive ports.

With the construction of Yangshan Container Port the container throughput of the hinterland of Shanghai Port and Yangshan, the Yangtze River area, is expected to increase. For the hinterland transport this will be an extra burden. The volume of containers transported over rail is expected to increase from 0.405 mTEU in 2005 to 0.951mTEU in 2010 while the volume transported by truck is expected to increase from 2.515 mTEU in 2005 to 6.829 mTEU in 2010. The expected increase of the volume of

containers transported by waterway is from 2.247 mTEU in 2005 to 3.180 mTEU in 2010.

According to the results of a Multi Criteria Analysis, the optimal performing transportation chains from Shanghai port and Yangshan port use the Yangtze River for hinterland transport. With transport being one of the major facilitators for trade, efficient transport over the Yangtze River can be used to push the economic development to the more western parts of the country. This is in line with the 'Go-West' policy of the Chinese government to diminish the pressure on the highly populated east coast.

The expected container flow over the Yangtze River shows that until 2015 transport of containers over the Yangtze is dominated by the container flow from Shanghai. After 2015 the container flow from Yangshan is taking over the dominant position. 25% of the containers transported over the Yangtze are transported to or from ports upstream of Nanjing; 30% of this volume has as destination Nanjing. With the water depth profile changing to 4.5 m. the port of Nanjing has the potential to become a transshipment port for the middle and lower reaches of the Yangtze River. Due to the high transported volumes between Nanjing and the coastal ports, a liner service is a good option.

The river section from Nanjing to Wusong is the best navigable section of the river with its depth of 10.5m. To contribute to the accessibility of the port of Nanjing, the required depth at the river mouth is maximum 10.5 m as this is also the depth of the more upstream section. For container transport to Nanjing dredging phase 3 would then not be necessary.

Being a transshipment port, the throughput of Nanjing will increase from 1.616 mTEU in 2005 to 2.829 mTEU in 2020. With this increasing throughput and an increasing number of calls the dimensions of the port should be adjusted. In 2005, the port of Nanjing needs 11 berths with a total length of 1,560 m. In 2010 this should be increased to 12 berths and a total length of 1,640m. For the year 2020 a quay length of 2,632 m is needed for 19 berths.

Table of Contents

4 Assessment of the hinterland network of Shanghai for future traffic absorption

5 Transportation chains between ports and hinterland destination

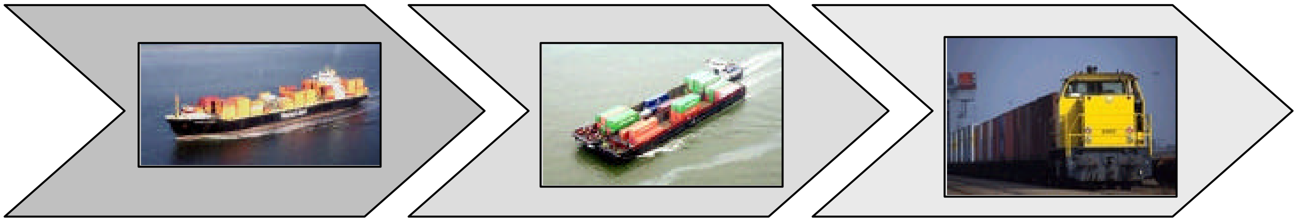
6 Long-term development aspects for transport in China

7 Multi Criteria Analysis

8 Usage of the Yangtze River for Container Transport

9 Development of the port of Nanjing

10 Conclusions and Recommendations



Factsheet China

Source EVD

Name country	People's Republic of China
Head of state	President Jiang Zemin
Land area	9,561,000 km^2
Capital	Peking (Beijing)

Population

Population (2001)	1,273.1 billion
Population growth (2001)	0.9 %
Language	Putonga or Mandarin

Economic indicators

GDP (2001)	1,159 billion US dollar
GDP per capita (2001)	910 US dollar
Growth GDP (2001)	7.3 %
Rise consumer prices (2001)	0.9 %
Currency	Renminbi or yuan (8.277 RMB = 1 US dollar)

Foreign trade

Total import (2001)	264.0 billion US dollar
Total export (2001)	232.2 billion US dollar
Main trade partners	Import from: Japan, USA, Taiwan, South Korea, Germany, Hong Kong, Singapore, Russia Export to: USA, Hong Kong Japan, Germany, South Korea, The Netherlands, United Kingdom, Singapore, Taiwan

1. Introduction

1.1. Container transport in China

> *-Due to the efficiencies created by standardisation the shipping industry has been able to lower the freight rates. Containers can be handled much more efficiently than loose cargo and are typically shipped via several modes of transportation, including truck, railway and ship. Container usage significantly reduces transport and port time, labour and handling costs and losses due to damage and paperwork-* ***(Drewry Shipping Consultants, 2002)***

From the passage above becomes clear that world wide containerised cargo knows a lot of advantages above non-containerised cargo. The world wide throughput of containers has accordingly seen a strong growth over the last decades. Also in China containerised cargo plays an increasingly important role.

Shanghai Port

The main container port of China is Shanghai, when excluding Hong Kong. In 2001 Shanghai Port took over the fifth position at the world container port ranking of the port of Rotterdam. The basis for this successful development of the port is partly found in its unique location.

Figure 1-1 Flow Huangpu River through Shanghai City

Shanghai Port is set against a vast hinterland, with a large manufacturing and consuming centre: Shanghai City, and the Yangtze River area where the major developed economic areas of China are found. With a population of 1.3 billion China offers a huge consumer market.

Since Shanghai began its container operations in 1978 the port has been undergoing remarkable and continuous container throughput growth. In the last decade the average throughput increased annually by over 25%. Two major limitations of the port of Shanghai are currently lack of capacity and insufficient water depth at the entrance channel and the berths.

In order to solve these problems the Chinese authorities decided to develop a new deep-water port. With this port Shanghai must strengthen its position as international shipping, trading and financial centre. After investigating the possible locations for this port the Chinese authorities decided to construct Yangshan Container Port.

Yangshan Container Port

Yangshan Container Port will become a 15 metre deep-water port located on the islands Dayangshan and Xiaoyanghsan at the Qiqu Archipelago in Huangzhou Bay. Yangshan Port is situated 100 kilometres from Shanghai and 30 kilometres from the mainland. A map of the location can be found in appendix 3. A bridge over the Huangzhou bay will provide the connection to the hinterland. The entire construction project of this new port consists of three parts.

- Construction of Luchao Harbour City
- Construction of the Luyang Bridge
- Construction of Yangshan Container Port

Figure 1-2 Location Yangshan (circle)

Luchao Harbour City will be a new city constructed on the mainland and able to supply all supportive services for the port. According to Chinese sources in 2020 this city will be populated by 200,000 to 300,000 people. The city will be constructed in accordance with a special design: in the middle a water area will be created, with the city build around it in circles Luchao Harbour city will have the appearance of a droplet**.**

Luyang bridge will make the connection between Luchao harbour City and Yangshan Port on the islands. The length of this bridge will be 32.2 kilometres and with six lanes it must be able to transport all containers from Yangshan to the hinterland. Over the bridge a rail line between the port and the city will *not* be built. Two sections of the bridge will be raised to allow vessels to pass underneath the bridge. The bridge is planned to be operational in 2005.

The construction of the port will be carried out in two phases. The first phase will involve the opening of five berths and is planned to become operational in 2005. Each berth will be able to handle 440,000 TEU. Container ships of over 5,000 TEU can call at the port. The total quay length of this first phase will be 1600 metres. The completed project, which will provide 52 berths, is expected to be finished in 2020. The final quay length is expected to be 18 kilometres. All berths together should be capable of handling 20 mTEU in 2020.

Hinterland transport

With the continuous growing throughput of Shanghai Port and the expected throughput generated by Yangshan Port, the pressure on the hinterland connections like road, rail and inland shipping is increased. For Yangshan Port the optimal transport chain using the various modalities still needs to be determined.

1.2. Problem Definition and Objective of the Thesis Project

Problem definition

> Lacking deep-water berths and sufficient capacity in the near future, Shanghai Port needs expansion to remain a competitive port in the top five ranking of world container ports.
>
> Yangshan Container Port must become the answer to the problems of Shanghai Port. A strong increase of throughput of Yangshan is expected once the port has become operational.
>
> With the container throughput growth of both Shanghai and Yangshan Port the pressure on the hinterland connections is likely to increase. The role of inland shipping in hinterland transport of both ports has so far been underexposed.

Objective

The objective of this thesis project is to determine the extend to what waterway transport can offer in the future a contribution to hinterland transport from Shanghai Port and Yangshan Port, and to determine the optimal performing hinterland transport chains and the required facilities when using waterways and taking into account the potential difficulties.

Approach of the objective

To determine to what extend waterway transport can be used in the future, it is necessary to determine the expected throughput development in the future. Therefore in ***Chapter 2*** an investigation is made into the current situation of the Chinese economy in relation to container trade.

In ***Chapter 3*** an analysis of the problems of Shanghai Port provides insight in the current situation of the port and relevant aspect for waterway transport can be determined.

The expected modal split of both ports is determined in ***Chapter 4*** followed by the examination of the capabilities of the current transport network of Shanghai's hinterland. Furthermore, combinations of transport modes are discussed.

In ***Chapter 5*** eight options are given for hinterland transport from Shanghai Port and from Yangshan Port.

Relevant aspects for long-term development of transport in China are outlined in ***Chapter 6.*** These aspects can influence the selection of the optimal transportation chain between the ports and the hinterland.

In ***Chapter 7*** the most preferred options are selected by using a Multi Criteria Analysis. With a sensitivity analysis the results are verified.

Suitability of the Yangtze River for container transport is examined in ***Chapter 8***. Beside the navigability of the river also the container flow over the Yangtze is determined.

With the calculation of the expected throughput in ***Chapter 9*** the number of calls at transshipment port Nanjing is determined as well as the global dimensions of the port for 2005, 2010 and 2020.

This thesis project is brought to a close with ***Chapter 10*** where conclusions and recommendations can be found.

1.3. Thesis Assignment

This thesis project has been done under guidance of Ballast Ham Dredging and Delta Marine Consultants.

Ballast Ham Dredging bv

The company is the result of the 2001 merger between Ballast Nedam Baggeren bv and Hollandsche Aanneming Maatschappij bv. Its services include the construction and maintenance of ports and waterways, land reclamation, coastal and shore protection works, marine pipeline burial and the remediation of polluted water beds.

Delta Marine Consultants bv

Delta Marine Consultants bv offers multi-disciplinary engineering and consultancy service. Its experience covers aspects of civil engineering related to the interface between land and sea, rivers, canals, lakes and other bodies of water, including the associated disciplines of environmental, coastal, offshore, geo-technical, structural, mechanical and electrical and marine operations engineering.

2. China, an Economic profile

With a population of 1.3 billion China is the most populated country in the World. The economic centre is found in the south-eastern regions where 90% of the population live. The provinces Hubei, Jiangxi, Anhui, Jiangsu and Zhejiang and the municipality Shanghai are responsible for a large share of the economical spin off. China's economy is continually obtaining a larger role in the world economy. The entry to the World Trade Organisation will further enhance its position. To push the economic development to the west, which is in line with the Go-West policy of the Chinese government, the Yangtze River can be used. The gates to this growing economy are the Chinese ports. Two Chinese ports, Shanghai and Shenzen, are found in the top ten ranking of Asian Ports. The purpose of this chapter is to give an introduction to the position of the Chinese economy and trade and to represent the implications for maritime transport.

2.1. China's geography and demographics

With 9.56 million square kilometres and a population of 1.3 billion, China is the world's largest and most populous country. The population is currently growing with 1% per annum and in 2050 a peak of 1.6 billion people is expected[1]. With this enormous population and a north-south distance of 4000 km and an east-west distance of 4800 kilometres, the Chinese government often experiences logistic, economical and political difficulties running the country from the capital Peking. The country is divided into 22 provinces, 5 Autonomous Regions, 4 Municipalities with Provincial Status, Chongqing, Peking, Tianjin and Shanghai, and two Special Administrative Regions (SARs), Macau and since 1997 Hong Kong.

China Characteristics		2000	2005	2010
Population (million)	Total	1,265,00	1,319,30	1,366,10
		1996-00	2001-05	2006-10
Averages per annum	Growth population (%)	1.0	0.8	0.7
	Growth working population %	1.2	1.1	0.8
	Birth rate (per 1000)	16.2	14.6	14.0
	Mortality rate (per 1000)	6.9	7.0	7.4

Source EVD, 2002

Table 2-1 Demographic profile

[1] [9]

The Chinese working population, which is important for the economic development, is expected to grow in the coming decade, even though the growth rate is decreasing to 0.8% in the period 2006 to 2010[2]. From the demographic profile in Table 2-1 can be seen that the changes of mortality and birth rates and the diminishing population growth are changing into the direction of figures found in well-developed countries. The Chinese development is well under way. Additional information about China is found in appendix 1.

China has a total coast length of 18,000 kilometres, excluding the 5400 islands that generate 12,000 kilometres of extra coast length. The coastal waters are shallow and natural harbours scarce. 90% of the total population live in the south-eastern coast provinces, which covers only 15% of the total land area. Currently, about 36.1% of the Chinese population lives in the urban districts. The social and economic differences between urban and non-urban area drove a lot rural inhabitants to the municipalities. Especially the coastal cities are very attractive because of the better economic development. The Chinese government is expecting a growth in the urbanisation rate of about 30 to 45 percent in de coastal municipalities Guangzhou, Shanghai and Peking by the year 2010[3]. To stop and turn around this process, which puts a lot of pressure on these municipalities, the government introduced a 'Go West'-policy. As outlined in the policy the western part of China receives a high priority when it comes to development of healthcare, infrastructure, agriculture and reforming of industry and education.

A consequence of the Go-West policy of China is the fact that development of the west is strongly supported by the government. Also foreign investors willing to invest in this part of China will receive high priorities from the Chinese government.

2.2. Economic Development of China

The most essential changes in the economic development of China in the recent past were the restructuring of the economy and the allocation of Hong Kong to China by the British. From the more recent economic development (paragraph 2.2.1) and the policy for future economic development (paragraph 2.2.2) can be seen that foreign trade is of great importance for China.

To promote industrialisation and growth, the Chinese economy has undergone restructuring and reorganisation during the last decades. The southern coastal regions have seen the most rapid development especially those designated as Special Economic Zones (SEZs). These SEZs, where businesses enjoy greater freedom from government

[2] [9]

[3] [29]

interference than in other parts of China, were founded in 1980[4]. Since 1984, fourteen coastal municipalities were also marked as SEZ and afterwards a lot of locations were added. Now there are hundreds of locations where foreign investors can settle themselves.

In 1997 Hong Kong was handed-over to China and gave China an important financial centre. Until 2047 Hong Kong will maintain its own political system although it is placed under the Chinese government: one country, two systems.

2.2.1. Recent Economic Developments in China

Two reasons made 2001 an important year for the Chinese economy.

1. The attack of the twin towers in the USA on the eleventh of September weakened the economy world wide. Also in China the consequences of this downward trend were noticeable in the trade growth because it slowed down. But even with this recess the trade growth figures of China remained positive, see paragraph 2.3.
2. In December 2001 China became a member of the World Trade Organisation (WTO). China had been negotiating a membership of the WTO for over ten years and needed to cut import barriers and quotas in order to satisfy the other 130 members. Governmental protection of the State Owned Enterprises (SOEs) is therefore no longer possible, and especially the first few years this will cause changes in the old economy with related difficulties. As a long term result, the Chinese market will open, import tariffs will be lowered and slowly the non-tariff obstacles will be reduced. The total climate for foreign investment will improve. Undoubtedly, membership of the WTO will prove to be a stimulant for national and international trade. On the other hand it is likely that the entrance to the WTO may cause some social and political instability. Therefore the rate of economic restructuring will diminish a little in 2002[5]. It will probably take time before changes introduced by the membership can be noticed because of the gradual implantation.

Now the welfare state China is being abolished, the inequality is rising and as a result the social pressure is enlarged. The reform and restructuring of several sectors like agriculture, social security, education, health care and state owned enterprises, is still continuing. But with the future being unsure, the Chinese started saving their earnings.

China's economic restructuring will not be complete without the reform of its State Owned Enterprises seeing that economic growth is held back by these predominant loss making enterprises. Many of the SOEs are regarded as a heavy burden for the Chinese economy. Big state loans meant for reform are being granted but they are often used for different purposes. Besides, released statistics from the state-sector are usually

[4] [31]

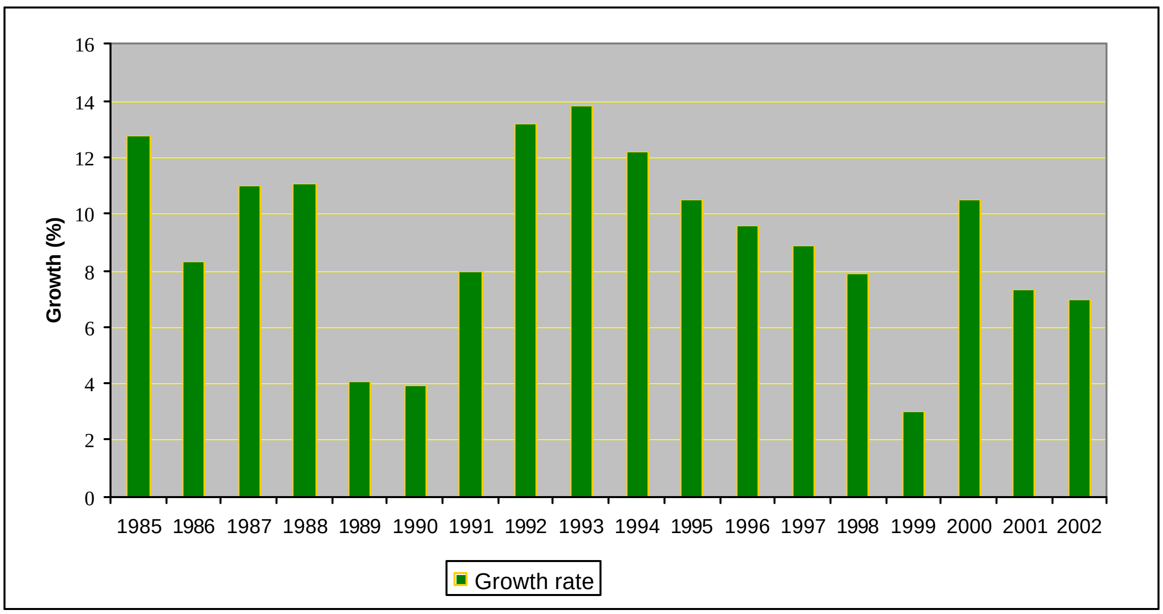
[5] [15]

unreliable because approximately 75% of the SOEs keep fictitious accounts[6]. Even on national level, political considerations, dictated by the central-planning policies, were in the past more important than economic growth. Therefore economic data were collected and edited for political purposes, which sometimes still takes place. When SOEs are made more efficient wide spread unemployment is expected[7]. To counter that, jobs need to be created rapidly for which economic growth is indispensable. Therefore foreign trade is becoming a more and more important factor for the Chinese economy.

The low labour costs make China a very interesting country for foreign investors. This is enhanced by the increasing globalisation. Many multinational corporations are sourcing their products globally, and China offers good conditions like the largest consumer market of the world. But it might take some time before China as a buyer's market is completely opened because currently the average income per capita is low. First an overall GDP growth in China is necessary.

Fastest GDP-growth in the World

An indicator for the economic development is the Gross Domestic Product (GDP) of China. From 1978 to 1989, China's GDP grew by 9.5 % per year[8]. During 1989-2001 the average growth was 9.3 %. In 2001 the mean GDP per capita was 19,803 RMB.



Source: Drewry Shipping Consultants,2002

Figure 2-1 Growth rate of the Gross Domestic Product

---

6 [29]

7 [29]

8 [7]

In 1997, the flooding of the Yangtze River and the Asian crises reduced the GDP growth for the following years. In 2000 China saw a recovery. This resulted in 10.5% growth of the GDP, much more rapid than the 3.0% in 1999. In the year 2001, when the world economy was strongly decreasing, the GDP growth rate in China was still 7.3%. In Figure 2-1 the GDP growth rate is given for the period 1985 to 2002.

Despite the downward trend from 1993 to 1999, China had the fastest growing economy in the world in this period, which raised China's status in the international community. For 2002 Chinese analysts expect a growth rate of 7.0%.

The generation of the GDP is not equally spread over the country. The southern regions of China, Guangdong, Hebei, Jiangsu, Liaoning, Shandong, Shanghai and Zhejiang, account for nearly 50% of China's total GDP[9]. In the decade up to the year 2000 the GDP of Shanghai increased by nearly 400%.

Challenges for China

The rapid development of the southern regions caused a major transportation problem for China as food production and energy sources are mostly situated in the northern and the western regions. A good logistic system should be a solution to this problem, but that would take time.

Another problem in the years to come is the unemployment China has to deal with. As a result of the WTO membership unemployment will probably rise, as explained earlier in this chapter.

working population	749.1 mln
unemployment	4.90%
labour cost per hour	0.6 US dollar

Source EVD, 2002

Table 2-2 Labour market of China in 2001

The Chinese government only publishes unemployment rates of the urban areas as given in Table 2-2, 4.9% in 2001. This rate excludes people working for SOEs, who officially still receive a salary, but actually have no employment. The World Bank estimates the real unemployment rate at 9 to 10%.

[9] [7]

2.2.2. China's Policy for Future Economic Development

The policy for future economic development is given in five-year plans by the Chinese government. The current five-year plan, 2001-2005, is the tenth five-year plan in row. This plan anticipates to the membership of the WTO, which means the government will less interfere with private enterprises and sectors. In this tenth five-year plan the role of the government is defined as following:

> *'To enforce the law and management and to concentrate efforts on macro regulation and control and creating a sound market environment, and not to directly intervene in enterprises' operational activities'*

The state sectors like energy, railway services and telecommunication should become competitive with the market. Major points of attention are the growth of the GDP, the reforms of different sectors and improving the average life standard. When the policy of the tenth five-year plan is converted to figures, the major guidance targets for the national and social development areas in 2001 are[10]:

- Economic growth rate of 7 percent
- Rise in consumer price level of 1 to 2 percent.
- Rise in total trade of around 8 percent
- Maximum registered urban unemployment rate of 4 percent.

For 2001-2005, China planned to maintain the rapid growth, while achieving great improvement in the strategic restructuring of the economy. This should improve the quality of economic growth to lay a solid foundation for doubling the GDP by 2010. The major macro-economic targets is to keep an average yearly economic growth rate of 7 percent and a maximum registered urban unemployment rate of about 5 percent in this period. The forecast for the GDP is 7 percent change year on year, both Drewry Shipping Consultants and ING Barings take this view on the GDP forecast.

In order to keep up with the rapid economic growth and China's entry to the WTO, the Chinese government will enhance the efficiency of ports and construct new container terminals, according to the 10th five-year plan.

2.3. Trade

Changes in the global and Chinese market environment cause changes in trade. Both import and export may be influenced. The main trade partners follow from the import

[10] [15]

and export figures. Trade is the main driver of throughput for ports. To determine the present economic position of China in the world, the world ranking of ports is therefore a good indicator. This paragraph will provide more insight in the above aspects.

2.3.1. Import and Export Characteristics of China

The weak position of the world economy in 2001 had a negative effect on trade. The consequences are visible in the import and export figures in Table 2-3. Both import and export growth was strongly diminished. The first semester of 2002 this was not yet restored[11]. But even though the figures diminished China climbed on the world ranking of trade nations in 2001. For the import a stronger rise than for the export is expected in the future.

	2000 (%)	2001 (%)
export growth	27.8	6.0
import growth	35.8	7.5

Source Drewry Shipping Consultants

Table 2-3 Figures of import and export of China

The main trade partners of China for import and export are given in Table 2-4. In 2001 the USA was with a share of 20.4% the main trade partner for export, while 10.8% of the total import came from the USA. At the end of May 2002 Chinese goods accounted for 9.3% of all USA imports. In 2001 this was 7.7%. Japan is with 17.6% the major import partner of China. Over time, the percentages of share per country are changing but the ranking of the trade partners is constant.

Export (%)	1999	2000	2001
USA	21.5	20.9	20.4
Hong Kong	19.9	17.9	17.5
Japan	16.6	16.7	16.9
EU		15.3	
Germany	4.4	3.7	3.7
South-Korea	4.0	4.5	4.7
The Netherlands	2.8	2.7	2.7
United Kingdom	2.8	2.5	2.6
Singapore	2.3	2.3	2.2
Taiwan	2.0	2.0	

Import	1999	2000	2001
Japan	20.4	18.4	17.6
EU		13.7	
USA	11.8	10	10.8
Taiwan	11.8	11.3	11.2
South Korea	10.4	10.3	9.6
Germany	5.0	4.6	5.7
Hong Kong	4.2	4.2	3.9
Singapore	2.5	1.0	
Russia	2.5	2.6	3.3
Malaysia		2.4	2.5

Source EVD,2002

Table 2-4 Main trade partners of China

[11] [8]

The Chinese export market has western countries but also less developed countries as important trade partners. The reason for that are the low labour costs in China, which make production costs low. Consequently, developed countries are part of China's distribution area.

2.3.2. Ranking of Container Ports

To get insight in the position of China's container ports global rankings are given as well as rankings of ports within Asia.

Global ranking of container ports

Shipping has played an important role in China's economic development, which in turn has given seaports opportunities for development. The result of the economic growth of the last decade is also visible in the world ranking of largest containers ports: In the 2001 top ten ranking of container ports, as given in Table 2-5, two Chinese ports are found besides Hong Kong; Shanghai takes the fifth position and Shenzen is number eight. These two ports handled together 50% of the total container throughput of China.

World ranking 2001 (2000)	Port name	Trade region	Total TEU
1 (1)	Hong Kong	East Asia	17,900,000
2 (2)	Singapore	South East Asia	15,520,000
3 (3)	Pusan	North East Asia	7,906,807
4 (4)	Kaohsiung	East Asia	7,540,000
5 (6)	Shanghai	East Asia	6,340,000
6 (5)	Rotterdam	Northern Europe	5,944,950
7 (7)	Los Angeles	North America Westcoast	5,183,520
8 (11)	Shenzen	East Asia	5,076,435
9 (9)	Hamburg	Northern Europe	4,689,000
10 (8)	Long Beach	North America Westcoast	4,462,971

Source Drewry shipping Consultants, 2002

Table 2-5 World ranking container ports

From Table 2-5 can also be concluded that the top five of container ports consists of only Asian ports, since Shanghai took over the fifth position of Rotterdam in 2001. It can be concluded that Asian countries have the highest container throughputs of the world. Actually the only non-Asian country in the top six of high country throughputs is the USA. The other countries in the top are China, Singapore, Japan, Taiwan and South Korea. These Asian countries together accounted in 2001 for 30.4% of the world total throughput as can be seen from Table 2-6. The share of China in 2001to the world total throughput was 9.3%.

(*1000 TEU)	1980	1990	1996	1998	1999	2000	2001
China	79	1,428	6,948	11,486	15,299	19,389	22,786
Hong Kong	1,465	5,101	13,460	14,582	16,211	18,098	17,800
Taiwan	1,644	5,451	7,866	8,858	9,758	10,511	10,426
Total East Asia	**3,188**	**11,980**	**28,275**	**34,926**	**41,268**	**47,998**	**51,011**
Japan	3,501	8,094	11,366	11,092	12,386	13,826	13,732
Sout Korea	702	2,538	4,898	6,048	6,900	9,120	9,728
Total North East Asia	**4,203**	**10,632**	**16,264**	**17,140**	**19,286**	**22,946**	**23,460**
Total North East and East Asia	**7,391**	**22,612**	**44,539**	**52,066**	**60,554**	**70,944**	**74,471**
World Total	38,772	87,783	157,140	189,250	209,026	235,056	244,787
Share China of World Total	0.2%	1.6%	4.4%	6.0%	7.3%	8.3%	9.3%
Share North East and East Asia of World Total	19.1%	25.8%	28.3%	27.5%	29.0%	30.2%	30.4%

Source Drewry Shipping Consultants ,2002

Table 2-6 Contribution of China to Total Throughput of North East and East Asia

From this table the rapid increase of the Chinese share can also be seen. In 1980 North East and East Asia accounted together for 19.1% of the world total throughput, the share of China was only 0.2%. Every year the Chinese share is increasing. For 2002 a share of 13% is expected for China[12].

Ranking of container ports within Asia

The position of China within Asia can be verified by looking at the Asian ranking of container ports, (Table 2-7). Of the twelve ports with the highest throughputs, two Chinese ports are found: Shanghai on the fifth position and Shenzen on the sixth position.

Rank 01	Port name	TEU 2000	TEU 2001
1	Hong Kong	18,100,000	17,826,000
2	Singapore	17,086,900	15,571,100
3	Pusan	7,540,387	7,906,807
4	Kaohsiung	7,425,832	7,540,524
5	Shanghai	5,613,000	6,340,000
6	Shenzen	3.751.973	4,430,577
7	Port Klang	3,206,753	3,759,512
8	Tokyo	2,899,452	3,759,512
9	Manila	2,867,836	-
10	Tanjung Priok	2,476,152	-

Source Drewry Shipping Consultants and others

12 [4]

Table 2-7 Asian ranking container ports

The competition between Asian ports is strong. For this reason the Chinese government decided in 1995 to develop Shanghai into a competent port to compete with Hong Kong for the first position of the world's largest container port.

Until now this has been successful, Shanghai is climbing in the top ten ranking. In 2002 Shanghai handled 25% of the total Chinese throughput that was 34 mTEU[13]. In 2001this was 22.79 mTEU, an increase of 49%.

Within China the port of Shanghai is the number one largest container port. The ranking of Chinese ports is given in Table 2-8.

Ranking Chinese Ports								
Rank 01	**Rank 00**	**Port name**	**TEU 2000**	**TEU 2001**	**Growth**	**1H2001**	**1H2002**	**Growth**
1	1	Shanghai	5.613.000	6.340.000	13.0%	2.940.000	3.840.000	30.6%
2	2	Shenzen*	3.751.973	4.430.577	18.1%	2.150.000	3.230.000	50.2%
3	3	Qindao	2.120.000	2.640.000	24.5%	1.300.000	1.610.000	23.8%
4	4	Tianjin	1.708.423	1.915.200	12.0%	950.000	1.150.000	21.1%
5	5	Guangzhou	1.430.000	1.601.600	12.0%	740.000	1.000.000	35.1%
7	6	Ningbo	902.100	1.210.000	34.1%	530.000	810.000	52.8%
6	7	Xiamen	840.000	1.290.000	53.6%	600.000	800.000	33.3%
unknown	8	Dalian	810.025	907.228	12.0%	550.000	580.000	5.5%
unknown	9	Fuzhou	399.800	418.000	4.6%	200.000	230.000	15.0%

* includes Yantian, Shekou and Chiwan

Source Drewry Shipping Consultants, 2002

Table 2-8 Ranking of Chinese ports

From this figures of 2001 can be seen that Chinese ports were not seriously hampered by the economic downturn of that year. Growth figures of even over 50% are found for Shenzen in the first six months of 2002[14].

2.4. Contribution of the East-coast Provinces to the Chinese economy

Of the provinces at the south-eastern part of the country are five situated in the economic belt along the Yangtze River. These are, going upstream, Jiangsu, Anhui, Jiangxi and Hubei. The Yangtze River discharges into the East Chinese Sea nearby

13 [43]

14 [8]

Shanghai Municipality. Other provinces with high economic importance at the south-east coast are Zhejiang and Guangdong. For the latter the port of Hong Kong is closer than the port of Shanghai. Therefore trade of Guangdong is mainly focussed on Hong Kong. In Figure 2-2 an overview of the provinces of China is given.

Figure 2-2 Map of all Provinces of China

The differences between the provinces are for a larger part due to differences in economic development, as demonstrated by differences in GDP and the importance of the primary, secondary and tertiary sectors. In appendix 2 additional information about the south-east coast provinces can be found. An overview of these main parameters is given.

The Yangtze River has opportunities to support the realisation of the Go-West policy of the Chinese government. Via this river the economy can be pushed to the west.

For that reason in this paragraph the provinces are described that can be influenced via development of the usage of the Yangtze River. An exception is made for Zhejiang Province. With its well-developed economy this province also might be of importance of the region.

Shanghai Municipality

Throughout the centuries, Shanghai has been China's most important industry and trade centre. Not very surprising since Shanghai, which means 'by the sea', has a very unique geographical position, located along the Huangpu River at the mouth of the Yangtze River and with a great catchment area. During the nineties the Chinese government decided to develop Shanghai into an important financial centre by the year 2010, which by then should be able to compete with Hong Kong. In 2001 Shanghai had a mean GDP per capita of 34,600 RMB.

Figure 2-3 Map of Shanghai Municipality

Jiangsu Province

Jiangsu is one of the most populous provinces of China. This high population creates opportunities for high industrial production of machines, fabric and electronics. The most important ports are the port of Nanjing and the port of Nantong. Especially Nanjing has a favourable position thanks to its natural navigation channels. In 2001 Jiangsu had a mean GDP per capita of 10,699 RMB.

Anhui Province

Being the capital of the province Anhui Hefei area has the main business, trade, information and finance centre of Anhui. Its main industries beside the agricultural industry are electronics, machinery, and chemistry. Steel and automobile industries are coming up. The container volume in Anhui Province is mainly generated in Hefei and Wuhu area, the latter is also the main port of Anhui. In 2001 Anhui had a mean GDP per capita of 4,660 RMB.

Jiangxi Province

The province Jiangxi has a function of transport between the Guangdong Province and the more inland provinces of China. Besides the production of wood that is produced in high volumes here, the last decades also the industrial development became important. Especially fabric, paper and chemicals are produced in this province. The main port of Jiangxi is Jiujiang. In 2001 Jiangxi had a mean GDP per capita of 4,640 RMB.

Hubei Province

In Hubei, large amounts of chemicals and building materials are produced. The main export products are steel and cars. The capital of Hubei, Wuhan, is situated on a central point along the Yangtze. This gives Wuhan the position of main transportation and distribution centre of Central China. Main industries are chemicals and fabric. A little upstream from Wuhan the 'Three Gorges Dam' is being built. The area around Wuhan can benefit from the economic effects since the dam attracts a lot of investments in the infrastructure and also in the power plant that is being built nearby. In 2001 Hubei had a mean GDP per capita of 6,494 RMB.

Zhejiang Province

Zhejiang is the smallest, wealthiest and most powerful province of China. It has a long trade history, mostly thanks to the fifty ports the province has. Looking at the economic growth, Zhejiang can be found in the top five of all the Chinese provinces. It is the centre of the fabric industry but also the trade sector is growing. Main export products are shoes, clothing, toys and chemicals. The largest seaport in Zhejiang Province is Ningbo. In 2001 Zhejiang had a mean GDP per capita of 12,000 RMB.

Regarding export of all provinces can be said that industry of high-quality products overtakes industry of the cheaper products: machinery took over the position of most important export product of the fabric industry. In 2001 high-quality products took on 45.0% of the Chinese export market. Most of these high-quality products are produced in Shanghai area and the Yangtze Delta area. These areas alone accounted for 34% of total export in 2001.

2.5. Conclusions of the Economic Profile of China

- As a consequence of the geography the Chinese economy is based on the east coast. With the high urbanisation rates and the high population, the government started a Go-West policy. Foreign investments in the western part of the country are therefore highly stimulated.

- China's recent membership of the WTO is an important development of the economic position of China. The membership will stimulate further trade growth and this will probably become more noticeable from 2003 onwards. Increasing container trades will be one of the main benefits of the membership of the WTO.

- The low Chinese labour costs are attractive for foreign investors. As a consequence of these low labour cost the production costs are lowered. The ongoing globalisation is thereby a stimulant.

- The Chinese government has given the development of ports and their efficiency a high priority in the 10^{th} five-year plan for the future economic development.

- 30% of the world total throughput was in 2001 transferred in North-East and East Asia. The Chinese share to the world total throughput is increasing every year. In 2001 it was 9.3%, for 2002 13% is expected. It can be said that the Chinese economy is booming as becomes also visible in the GDP growth, which is the fastest in the world.

- As the largest manufacturing, trading and consuming centre in China, Shanghai's economy has benefited from the reform policy, with the GDP of Shanghai increasing by nearly 400 % in the decade up to the year 2000. Shanghai is the number one on China's largest container port ranking.

- The Yangtze River can be used to push the economic development from the east coast to the more western provinces of the country.

3. Problem Analysis of Shanghai Port

3.1. Introduction to Shanghai's port capacity

With booming economies in Asia and especially in China, the prognoses for Shanghai Port seem to flourish unlimited. Figures of the container throughput of Shanghai of the last decade subscribe this vision on the port.

Throughput Shanghai Port			Total Throughput World		
Year	million TEU	Growth (%)	Year	million TEU	Growth (%)
1990	0.456	-	1990	87.,8	-
1991	0.577	26.5	1991	96.3	9.7
1992	0.731	26.7	1992	105.8	9.9
1993	0.935	27.9	1993	116.5	10.1
1994	1.199	28.2	1994	130.7	12.2
1995	1.526	27.2	1995	144.6	10.6
1996	1.971	29.2	1996	157.1	8.6
1997	2.527	28.2	1997	175.0	11.4
1998	3.068	21.4	1998	189.3	8.2
1999	4.210	37.2	1999	209.1	10.5
2000	5.610	33.3	2000	235.1	12.5
2001	6.340	13.0	2001	244.8	4.1
2002	8.610	34.0	2002	263.1	7.5

Source Drewry Shipping Consultants ,Barings, Deutsche Verkehrs Bank [8], [15], [4]

Table 3-1 Throughput Shanghai and World

With Table 3-1 can be found that the average throughput growth of Shanghai Port over the last 10 years was 28%. Although the first digit of the growth was often above 30% since 1999, the average growth was again around 28% over the last five years as a consequence of the growth decline in 2001. Comparing the growth figures of Shanghai Port with the growth figures of the total container throughput of the world, one can conclude that Shanghai strongly exceeds the average world wide container throughput growth. Over the last ten years the average throughput growth of the world was 9.6%, in the last five years it was 8.6%.

In Figure 3-1 the growth percentages of the total throughput of Shanghai and the world are presented.

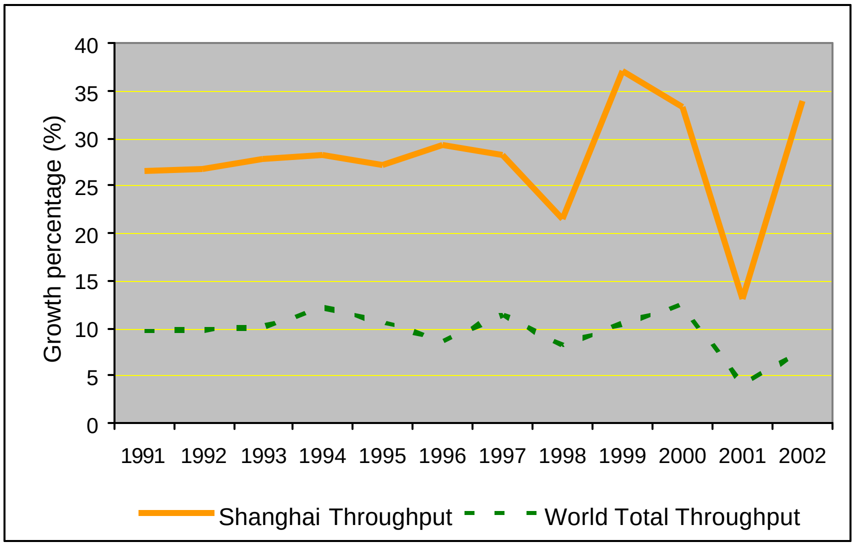


Figure 3-1 Growth percentages of Container Throughput for 1991-2002

In 2001 a world wide sharp decrease in the growth development appeared. Even then the growth figures of Shanghai Port were eminently higher than the mean growth figures of world wide container throughput growth. Since 1995 the position of the port of Shanghai was consolidated even more. The Chinese government decided to establish Shanghai as the economic, financial, trade and international shipping centre of China, with the capability to compete with Hong Kong. As a result, high governmental priorities were given to the development of the port.

Even though the figures for the throughput growth and the total container volume of Shanghai are rising sky-high and the port has full governmental support, the future is not only as bright as it seems. Shanghai is facing several difficulties and some of these difficulties can even grow worse with the increase of the container throughput. In this chapter a problem analysis of the port of Shanghai is given, considering the trade position of Shanghai in Asia, the capacity problem of the port and the accessibility of the port.

3.2. Trade Position of Shanghai in Asia

Located in the centre of the economic development in Asia, the port of Shanghai has a unique position. A disadvantage of this location however is the fact that Shanghai experiences rough competition from other seaports in the area with the same ambitions, like Kobe, Pusan, Kaohsiung and Hong Kong. With 510 kilometres Pusan is the nearest competitive port.

Figure 3-2 Competitive ports around Shanghai and their mutual distances

Shanghai-Hong Kong	930 km
Shanghai-Kobe	850 km
Shanghai-Kaohsiung	680 km
Shanghai-Pusan	510 km

Currently direct trade between China and Taiwan, and therefore between Shanghai and Kaohsiung, is prohibited. Trade between these countries is mostly transferred via Hong Kong. In 2000 the China-Taiwan trade accounted for 1 mTEU or 8.6% of the throughput of the Kwai Chung Terminal of Hong Kong Port. Liberalisation of the trade link is expected around 2003-2004 while direct passenger transport is already admitted. Direct trade between China and Taiwan will cause an increase of the throughput of Shanghai. The prognoses are that 100% of the North and Central China-Taiwan trade and 65% of the South China-Taiwan trade will have switched to direct trade in 2010[1].

[1] [15]

The competition between the ports is mainly focussed on the contestable hinterland and the contestable port destinations. Contestable hinterland is the geographical market-share that still can be conquered by the neighbouring ports while the contestable port destinations are the destinations that still can be conquered. An example is given in Figure 3-3.

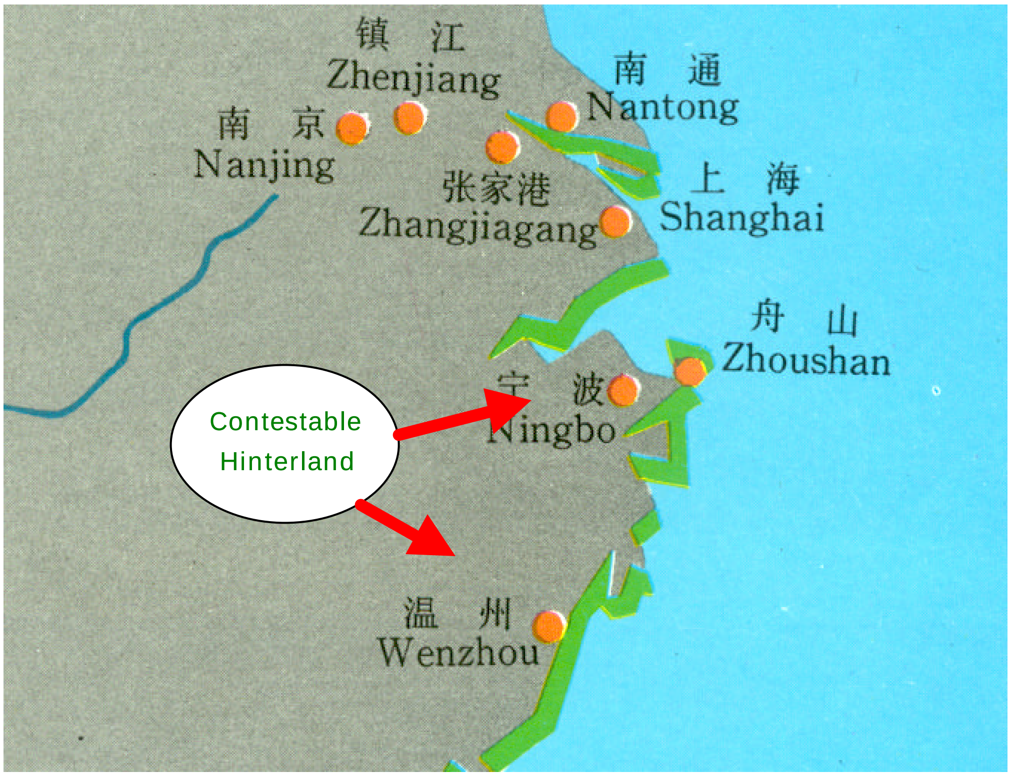


Figure 3-3 Example of Contestable Hinterland

Concerning the contestable hinterland of Shanghai, it can be posed that Hong Kong has an advantage above Kobe and Pusan. The latter ports are lacking land connections with China and therefore have no direct access to the contestable hinterland of Shanghai Port.

Not only is the position to the contestable hinterland determining for the competitive position also the attractiveness for liners is of importance. When a port is attractive for liners, because of good location in combination with good facilities and services, more vessels will call at the port. Liners might decide to call at the port frequently and as it is uneconomical to operate container ships calling at several ports, the port might obtain a hub function. This is supported by the fact that containerships are growing larger and operators are moving more and more towards transshipment[2] of containers at hub

2 Sea-sea transfer

ports. As a consequence the port improves its position to the contestable hinterland compared to competing ports. An increasing throughput might again be the result.

Transshipment is a throughput generator, but not an unlimited one. When regional ports are gaining importance, direct services will take over more and more cargo and the transshipment can be reduced again. The fact that China has unfavourable coastal conditions for seaports and only a few natural harbours can be found along its coast reduces the national competition for Shanghai. From the ranking of Chinese ports in Chapter 2 can be seen that other ports with high throughputs are relatively far away from Shanghai, except for the port of Ningbo. The competition from other Chinese ports is therefore limited. This might change when a new bridge with a length of 36 kilometres is constructed over the Huangzhou Bay to Ningbo.

When Shanghai is not able to hold the vessels on to its port and to attract more vessels by offering good facilities and good services, the attractiveness for liners is reduced. Vessels can easily divert to competitive ports like Hong Kong and Pusan. This can cause loss of throughput for the port of Shanghai. Sustained growth is therefore essential to the port of Shanghai.

3.3. Capacity problem

When the throughput of a port exceeds its design capacity problems might occur. To determine the potential size of the capacity problem, Shanghai port's design capacity is compared with its expected throughput in this section.

3.3.1. Current Capacity of Shanghai Port

At present, container operations in Shanghai are divided into two container handling areas namely Shanghai Container Terminal and Waigaoqiao.
The Shanghai Container Terminal (SCT) consists of three dedicated container terminals at Zhang Hua Bang, Jun Gong Lu and Boa Shan. The terminals are all located at the Huangpu River banks. Together they account for 2,281 metres of quay length and a total annual design throughput capacity of 1.7 mTEU.

Shanghai Container Terminal	No. of berths	Design Throughput capacity (*000 TEU)	Depth at berths (m)	length (m)
Zhang Hua Bang	3	800	12.5	783
Jun Gong Lu	4	650	10.5	858
Bao Shan	3	250	9.4	640
Total	10	1700	-	2281

Source China Shipping, 2000 and Containerisation International 2002 [18], [3]

Table 3-2 SCT terminals

With all these terminals lying at the Huangpu River banks, Shanghai port is experiencing an important limitation. With the vessel sizes increasing the dimensions of the river are becoming more and more a problem. Section 3.4.2 will return to this aspect. For the port of Shanghai a terminal expansion at other locations was necessary and from 1995 onwards the Waigaoqiao terminals were the result. In the figure below the represented Baoshan terminals are not the container terminals. These are located along the Huangpu River.

Figure 3-4 Locations of terminals of Shanghai Port

The terminals of Waigaoqiao (WGQ) are situated along the Yangtze River mouth between Shanghai and the East China Sea in a development zone, the so called Free Trade Zone. The terminals of WGQ are brought into operation in four phases. Phase 1 became operational in 1995 with a throughput capacity of 900,000 TEU, followed by phase 2 in 1999 with 600,000 TEU. In 2001 phase 3 became operational and added 400,000 TEU to the throughput capacity of the port. The last phase of the WGQ project, phase 4 is planned to be operational in 2004 and should add 1,000,000 TEU to the design throughput.

Waigaoqiao	No. of berths	Design Throughput capacity (*000 TEU)	Depth at berths (m)	length (m)
Phase 1	3	900-1,000	10	900
Phase 2	3	600-800	13	900
Phase 3	2	400	13	680
Phase 4	up to 6	1,000	13	unknown
Total	14	2,900-3,200	-	-

Source ING Barings, Radar [15]

Table 3-3 Waigaoqiao terminals

At present, without phase 4, WGQ is good for a total quay length of 2,480 metres and a total design throughput capacity of 1.9 mTEU when the low prognoses for phase 1 and 2 are taken. The future length of the quays of phase 4 is unknown. For that reason the final total length of WGQ is not presented in Table 3-3.

Following from above it can be estimated that the current total design capacity of Shanghai (SCT and WGQ phase 1, 2 and 3) is 3.6 mTEU.

WGQ is not the only location used for expansion of container terminals. Two more locations have been put forward, namely Wahaogou and Jinshan Zui.
Wahaogou area is lying 10 kilometres south of Waigaoqiao and a four-berth container terminal is planned to be developed. The start would be in 2003 and 400,000 TEU will be added then to the capacity of the port and another 400,000 TEU in 2005. The total design throughput capacity of Wahaogou will be 800,000 TEU.
Jinshan Zui is planned at the southern tip of Shanghai municipality. This terminal has a total design throughput of 800,000 TEU of which the first 400,000 will become operational at the end of 2002 and the last 400,000 in 2004.

Knowing the expected terminal expansions of the port of Shanghai in the future, the total design capacity over time can be determined. In Figure 3-5 the development of the capacity growth is given.

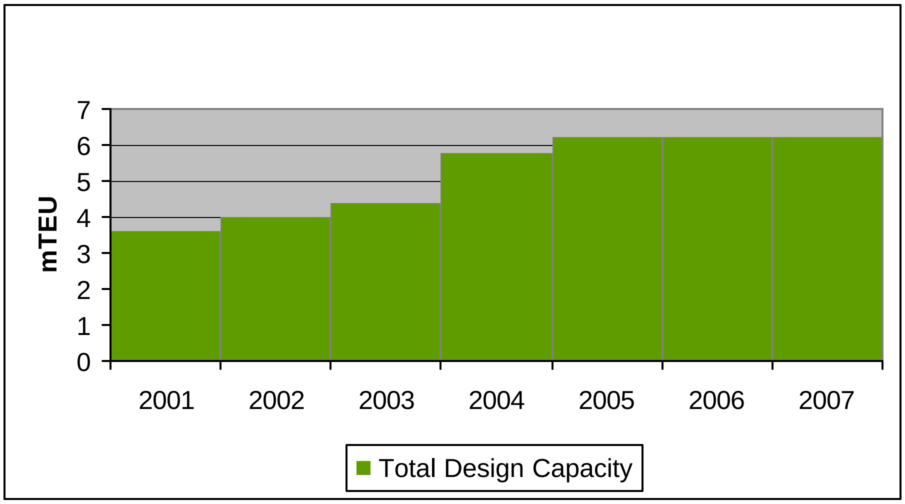


Figure 3-5 Total design capacity of Shanghai Port 2001-2007

In 2002 and 2003 0.4 mTEU of Jinshan Zui and Wahaogou terminal each will be added respectively to the 3.6 mTEU design throughput capacity of Shanghai. In 2004 the total capacity increase is 1.4 mTEU with the second half of the Jinshan Zui capacity and the 1.0 mTEU from phase 4 of Waigaoqiao. In 2005 the last 0.4 mTEU is added to the capacity and with that the total capacity comes to 6.2 mTEU.

With the design capacity being 3.6 mTEU, with the first phase of Jinshan Zui maybe 4.0 mTEU the question rises how Shanghai Port was able to reach a throughput of 8.6 mTEU in 2002.

3.3.2. Design Capacity versus Actual Throughput

When the design capacity of Shanghai is compared to the development of the throughput, as given in Figure 3-6 it can be seen that since 1998 the throughput is exceeding the design capacity.

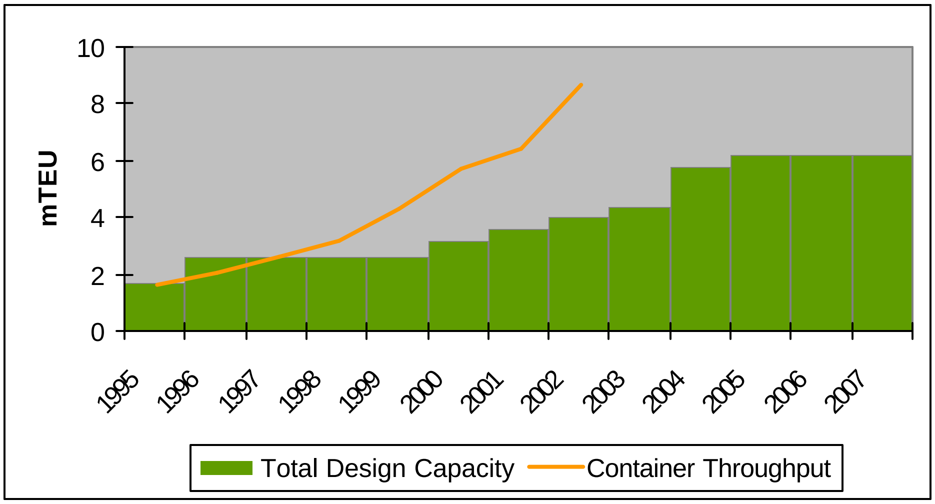


Figure 3-6 Total Design Capacity of Shanghai versus throughput development

When the throughput is increasing, the difference between the design capacity and the throughput is enlarged more and more in the future when no extra design capacity is added. An explanation for the fact that a port can realise a throughput above its design capacity is the high efficiency:

> When on the landside of the port, the container handling is operated with a high efficiency the design capacity can be increased to an effective capacity. A higher efficiency can be achieved by fast transport services between quays and stacks and terminal process improvements for example. Another creative way which is used to increase the efficiency is to lift two containers in one crane movement instead of one.

The throughput of a port is also increased by the fact that TEUs can be double counted.

> When containers are brought in by vessel, oceanic trade or local trade, and are directly transshipped to other vessels double counting of TEU occurs. With direct transshipment a TEU is passing the quays of the port twice and is therefore also found twice on the throughput count. The percentage of direct transshipment is called the transshipment incidence. Currently Shanghai has a transhipment incidence of 40%[3]. Estimated 40% of the throughput is double counted.

[3] [18]

3.3.3. Limitations to Shanghai's capacity

Although the capacity of the port can be stretched, there are limitations. With growth percentages over the last years of above 30% the capacity of the port is clearly one of the major problems of Shanghai Port. The question rises for how much longer Shanghai will be capable to manage this growth without expansion of its capacity. With the capacity of the port and the current transshipment factor being familiar, a prognoses can be made for the port of Shanghai. Therefore the effective capacity of Shanghai is needed. According to investigations of ING Barings[4] the effective capacity was in 2001 5.4 mTEU for all operating terminals of Shanghai Port together. When the design capacities of the new terminals are added to this effective capacity and a transshipment factor of 0.4 is applied, the result of the total throughput compared to growth scenarios for the throughput can be determined. A graphically representation is given in the figure below.

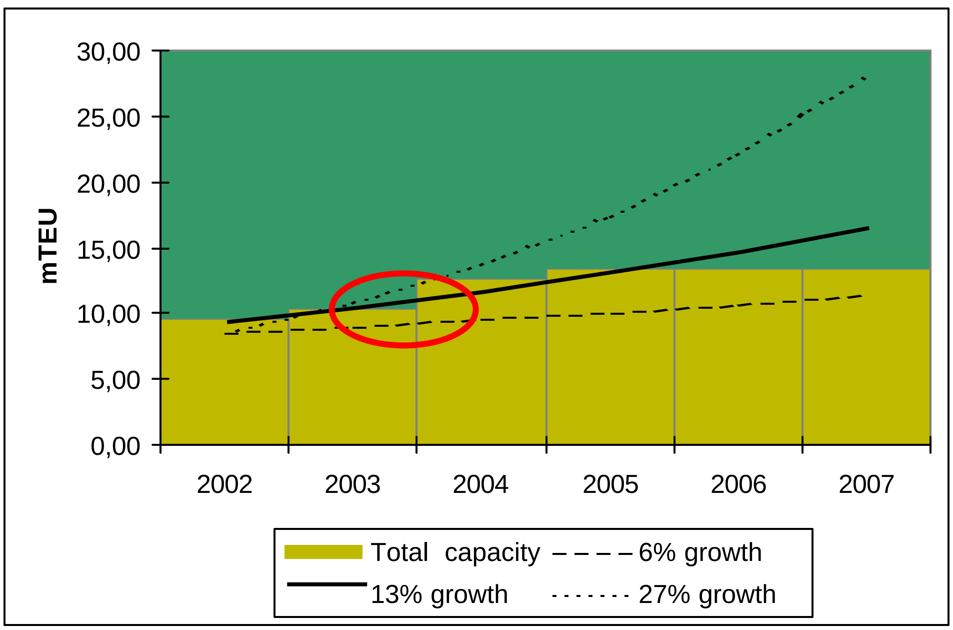


Figure 3-7 Capacity of Shanghai versus throughput scenarios

From the figure above can be seen that at the end of 2003 the throughput with the growth scenarios of 13% is exceeding the capacity while the 27% growth scenario is exceeding the capacity at the beginning of 2003. It must be noted that for the new terminals the design capacity is used as the effective capacity is not available. With the annual growth percentages of over 30% it is likely that at the beginning of 2003 the maximum capacity of the existing terminals is reached.

[4] [15]

According to the Chinese Design Water Institute (CWDI) the maximum capacity for Shanghai port is 10 mTEU. With 8.6 mTEU throughput in 2002 a throughput growth of 16% in 2003 will make the port reach its maximum capacity of around 10 mTEU. As a growth of 16% is for Shanghai very likely the port will face a major problem.

Beside the possibilities to enlarge the capacity of the port from inside, it might also be possible to create capacity back up from other ports. Only possible backup comes from Ningbo with its favourable natural conditions and its good location in the area of Shanghai. In 2000, total container throughput of Ningbo was 0.9 mTEU, only 16% of the throughput of Shanghai. In the 3rd quarter of 2002 this port had however a growth of 54.2% and therefore enough difficulties to keep up with its own growth. Ningbo can, for that reason, not offer real backup for the throughput growth of Shanghai but will probably benefit from the growing throughput of Shanghai.

3.4. Accessibility of the Port of Shanghai

A free entry to a port is of major importance for each port. In the case of Shanghai it can be posed that Shanghai is suffering from depth restrictions. This is caused by the rather shallow navigation channel that forms the connections between the port and the sea. With the absence of other deep water locations near Shanghai, the seagoing navigation is forced to use the estuary of the Yangtze River to enter the port.

3.4.1. Depth restriction of the Entrance Channel

The estuary of the Yangtze River is stretching over a length of 140 km from the sea. At the mouth of the Yangtze River the natural water depth is 5 to 6 metres below Chart Datum. However, the depth of the navigation channel was maintained at 7 meters below Chart Datum by dredging for a long time. In the appendix 3 a map of the mouth of the Yangtze River can be found. With a depth of 7 metres vessels of over 10,000 ton could only reach the port of Shanghai when using the tide. Larger vessels needed to be (partly) discharged outside the estuary[5]. Currently the depth of the entrance channel is 8.5 below CD.

The tide near Shanghai is semi-diurnal and the tidal range approaches zero at Datong, at a distance of 640 km from the sea. Below the water levels for mean high water spring, mean high water neap, mean low water neap and mean low water spring in the river mouth are given.

- ? MHWS 4.1m above CD
- ? MHWN 3.0 m above CD
- ? MLWN 1.6 m above CD
- ? MLWS 0.5 m above CD

CD is approximately the level of the Lowest Astronomical Tide. According to this at high tide a depth of about 12 metres is available in the river mouth. The mean tidal currents in the estuary are 1.00 m/s. The V max,flood is 1.70 m/s while the V_{max}, ebb is 1,67 m/s.

[5] [25]

Natural conditions

The depth restriction of the river mouth is mainly caused by the natural conditions of the river and the high sediment flow from the Yangtze River. The yearly run-off of the Yangtze is $912*10^9$ m^3 with a mean discharge of 32,400 m^3/s, a maximum discharge of 92,600 m^3/s and a minimum discharge of 4,620 m^3/s. In comparison with the Rhine the Yangtze has a mean discharge which is almost 15 times as high. This discharge also transports yearly 0.5 billion tons of sediment[6] with a mean silt concentration of 0.54 kg/m^3 to the river mouth. At the satellite photos in Appendix 4 the sediment flow can clearly be seen. The salinity in the river mouth is on average 16 permillage.

Figure 3-8 ***Yangtze Estuary***

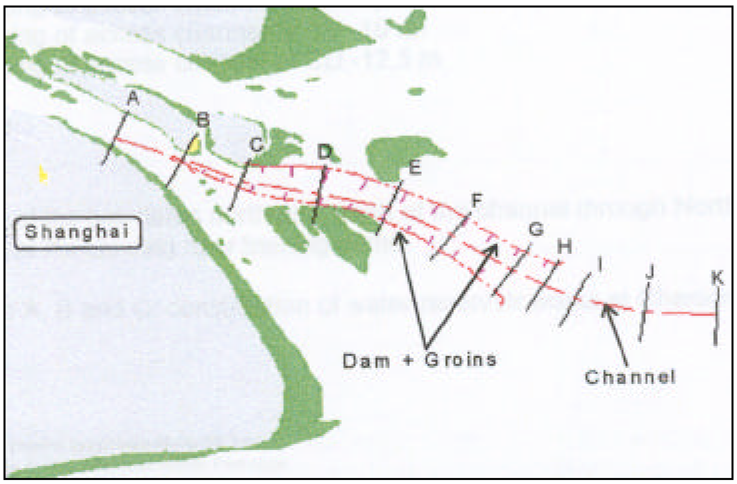
The estuary is split into several channels. It is bifurcated by the Chongming Island into North and South Branches (see also Appendix 3). The former undergoes serious accretion with a run off of 2 to 6% of the total run-off. This north branch is 4 to 5 meters deep and navigable for ships of around 500 tons. Because of problems with the salinity and sedimentation of this North branch two alternative plans are developed. The first plan is based on narrowing the channel while the second plan is based on complete blockage. In any case, Shanghai Municipality wants the channel to be closed completely while Jiangsu Province wants to keep it partly open. Reasons therefore are the development of its ports and the preserving of the channel as drainage channel. Unofficial sources indicate that narrowing may proof the first step of blocking, when dredging is found not to be feasible.

The South branch of the estuary is the main passage for run-off and navigation and is further divided into north and south channel by Changxing and Hengsha Island. Finally the south channel is again bifurcated into the north and south passage. To maintain the navigability of the South channel regulation of the North passage started in 1998.

[6] [25]

Regulation of the South Branch

The improvement scheme for the entrance channel consists of the construction of regulation works and a dredging programme. The locations of the regulation works in the river mouth can be seen in Figure 3-9. The function of these regulation works is to confine and control the current and to increase the sediment carrying capability of the channel. Furthermore the dam plays a role of intercepting of the long shore sediment transport. It is envisaged that the regulation works in combination with appropriate dredging operations would lead to the creation of the required deep channel for navigation. In 2000 the first stage of the north and south dams were completed.



Source Yangtze Pilot Project, 1999 [25]

Figure 3-9 Regulation works at the entrance channel

The dredging programme for the entrance channel was initiated in 1998 just like the regulation works and consists of three phases in which the entrance channel will be deepened to 12.5 metres.

-Phase 1 dredging to CD-8,5m
-Phase 2 dredging to CD-10m
-Phase 3 dredging to CD-12.5 m

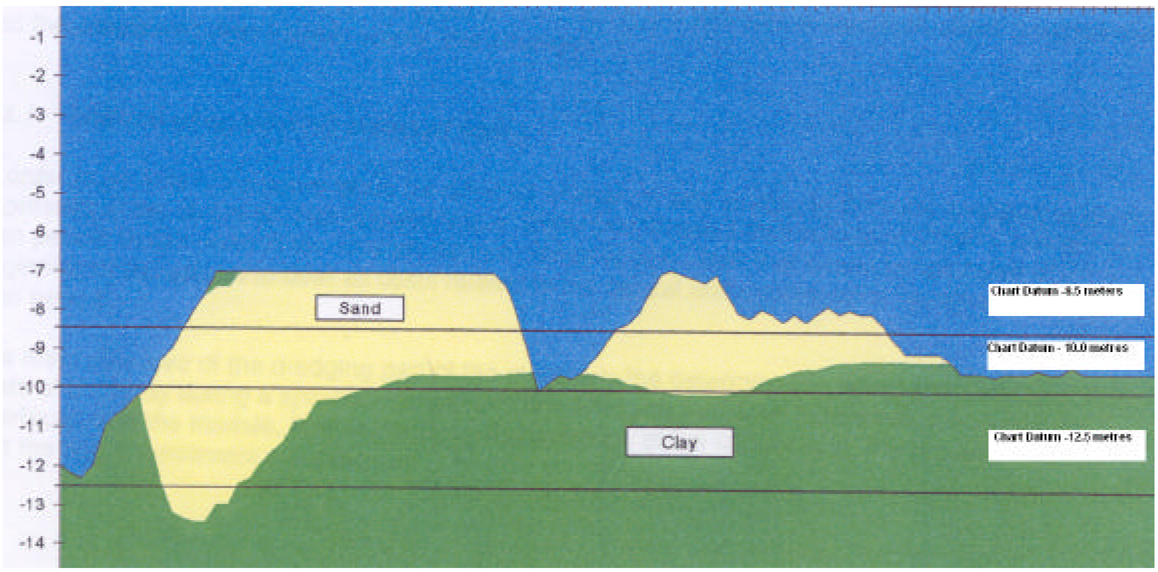
Phase 1 of the dredging programme started in 1998 and was finished in 2000. The total capital dredged volume to reach a depth of 8.5 metres below CD was 26.6 million m^3. The yearly volume to be dredged is estimated to be 23.0 million m^3 to keep the channel at this depth. Phase 2 (with a duration of 3 years) is planned from 2001 to 2003 and phase 3 (duration four years) is planned from 2003 onwards. The volumes for capital and maintenance dredging are given in Table 3-4.

Section	Dredging to CD-8,5m		Dredging to CD-10m		Dredging to CD-12,5m	
	Capital mln m^3	Maintenance mln m^3/year	Capital mln m^3	Maintenance mln m^3/year	Capital mln m^3	Maintenance mln m^3/year
Total	26.6	23.0	58.4	27.0	138.3	41.8

Source Yangtze Pilot Project [25]

Table 3-4 Volumes of Capital and Maintenance Dredging of the Entrance Channel.

For each channel section in Figure 3-9 the volumes of capital and maintenance dredging is given in the appendix 5. The longitudinal soil profile of the entrance channel is given in Figure 3-10. In this figure can be seen how the dredged material is composed.



Source Yangtze Pilot Project [25]

Figure 3-10 Longitudinal soil profile between the dams of the entrance channel

The deeper the channel will be dredged, the more clay has to be removed.

Even though phase 2 was planned to start in 2001 currently the start is not made yet. Unofficial sources indicate that the planning of the dredging programme is adjusted to the construction plans of Yangshan Port. Apparently all dredging equipment is needed at Yangshan and also the political priority seems to be at Yangshan Port. The continuing of phase 2 and three of the dredging programme might be cancelled according to rumours.

3.4.2. Vessel Depth Importance

The purpose of the dredging programme is to be able to receive also the new large vessels, without or with less discharging of vessels. The importance of this to the port can be subscribed by an investigation of Drewry shipping consultants. Drewry Shipping Consultants calculated that transport by a 6,000 TEU Post-Panamax container vessel with full slot capacity could offer 20% cost advantage over transport by a 4,000 TEU Panamax vessel[7]. Therefore large sized vessels are interesting for liners. A consequence of using large size vessels is that calls are only made at large hub-ports. A hub-port attracts extra throughput when these large vessels are calling and consequently it is comprehensible that Shanghai is aspired to strengthen their position as hub port. Therefore deep-water berths are of great importance and the impact on the throughput will be noticeable. For example, 20% of the total throughput of the port of Shanghai is currently first transshipped at Hong Kong as the berths of Shanghai are not deep enough. When Shanghai is able to facilitate 5,000 and 6,000 TEU vessels it has the possibility to gain the 20% extra throughput from Hong Kong.

To determine what percentage of the world fleet would be able to reach the port of Shanghai at all different phases of the dredging programme, first an investigation of the fleet is needed.

Investigation of the fleet

Shanghai is mainly a container port. Therefore this paragraph only investigates container vessels. A division between container vessels is generally made by TEU capacity (see Table 3-5).

Class	TEU capacity	DWT (average)	L(m)	D(m)	B(m)
1st generation	750-1100	14.000	180-200	9	27
2nd generation	1500-1800	30.000	225-240	11,5	30
3rd generation	2400-3000	45.000	275-300	12,5	32
4th generation	4000-4500	57.000	290-310	12,5	32,3
Post Panamax	4300-4600	54.000	270-300	12	38-40
Jumbo	>6000	80.000	310-350	14	42,8

Source Ports and Harbours [17]

Table 3-5 Container generations

This table shows the dimensions of the various generations of container vessels. Also the TEU capacity and the average DWT are presented. Table 3-5 shows only dedicated container vessels. But it must be noted that also other vessels often transport containers. In Table 3-6 the slots division of the entire world fleet is given.

7 [8]

Estimated Container Capacity end 2001	('000) TEU
Container Ships	5,404
Multi-purpose	898
Ro-Ro	372
Cargo Liners	95
Cargo Tramps	33
Conbulkers	412
Barge/ Hvy. Lift	21
Pure Car Carriers	24
Reefer	67
Total	7,325

Source Deutsche Verkehrs Bank [4]

Table 3-6 Estimated container Capacity, 2001

At the end of 2001 the dedicated container ships were with 5,404,000 TEU controlling 74% of the total container slot capacity of the world. Therefore is assumed that the focus of the port of Shanghai will be on these dedicated vessels.

Over time container ships are getting larger and larger. This can be seen from Table 3-7.

(TEU)	Average Ship Size	Average Newbuilding deliverd in year	Largest containership deliverd in year
1990	1,335	1,717	4,409
1991	1,362	1,756	4,427
1992	1,393	1,834	4,469*
1993	1,425	1,839	4,422
1994	1,461	1,812	4,743*
1995	1,494	1,813	4,960*
1996	1,539	1,913	6,418*
1997	1,593	1,987	7,060*
1998	1,646	2,193	7,060*
1999	1,745	2,224	7,060*
2000	1,824	2,945	7,060*
2001	1,897	3,420	7,500*

*Source Drewry Shipping Consultants *Post Panamax*

Table 3-7 Increase of Containership Size

From the table one can see that the size of the largest ship is increasing. In 1990 the largest ship had a capacity of 4,409 TEU while in 2001 this was 7,500 TEU, an increase of almost 70%. Not only the size of the largest vessel is increasing, also the size of the average ship is increased with 42%. A consequence is that the contribution in terms of percentages of the larger vessels is increasing. For example, the post-panamax with a capacity of more than 4,300 TEU, according to Table 3-5, now represents around 23% of the total fleet in TEU terms compared to just 4% in 1995. Table 3-8 shows the capacity division in TEU of the total world container fleet.

Size Range TEU	No. of vessels	%
<500	435	15.0%
500-999	467	16.1%
1.000-1.499	468	16.1%
1.500-1.999	425	14.6%
2.000-2.499	269	9.3%
2.500-2.999	243	8.4%
3.000-3.999	230	7.9%
4.000-4.999	182	6.3%
5.000-5.999	110	3.8%
6.000+	75	2.6%
Total	2.904	100%

Source Drewry Shipping Consultants,2002

Table 3-8 Container size range of the World fleet

With Table 3-8 and Table 3-5 one can determine which percentage of the fleet can enter the port at all dredging phases.

If Shanghai wants to keep up with the throughput growth which is of major importance for its international position, it also needs to keep up with the increasing vessel sizes

Accessibility per dredging phase

With the first dredging phase the depth of the entrance channel is brought to 8.5 metres below CD. With a low tide level of 0.5 metres above CD, at low tide a depth of 9.0 metres is available in the entrance channel. With an under keel clearance of about 1.5 metres the maximum draught of a vessel is 7.5 metres. With this depth even first generations can not enter at low tide the port. When the tide caused a water level rise of 1.5 metres first generation vessels, almost 40% of the entire world fleet, can enter.

The second dredging phase has a depth of 10 metres below CD. Again with an under keel clearance of 1.5 metres and the low tide being 0.5 metres above CD the maximum draught of the vessels at low tide is 9 metres. This means that first generation container vessels can enter the port freely. When using the tide vessels up to 50,000 ton can enter the port. According to Table 3-8 46% of the world container fleet can enter the port all day. Using the tide also second generation vessels can enter without discharging. Together with the first generation more than 60% of the entire fleet can enter the port.

The last dredging phase, with a depth of 12.5 metres below CD makes more free entries all day possible. With an under keel clearance of 1.5 metres and the low tide being 0.5 metres above CD vessels with a draught of 10.5 metres can enter at low tide. When tide caused a water level rise of 1 metre first and second generation vessels can enter. This is 60% of the entire fleet. Both third and fourth generation can enter the port even as post panamax vessels when using the tide. According to Table 3-8 about 90% of the world container fleet can enter the port.

3.5. New deep-water container port

As became clear that Shanghai Port has a lack of deep-water berths and will face a capacity problem in the near future an answer to these problems is found in the construction of a new deep-water port. It can provide extra throughput capacity and offer services for large container vessels. The international position of Shanghai can be strengthened by the construction of a deep-water port.
After investigations to the most suitable location according to the Chinese authorities, the Yangshan island were selected as location for the new port as described in Chapter 1. According to the problem-analysis for Shanghai Port it is very important to increase the capacity as soon as possible. The construction of Yangshan Container Port started in 2002 and the first phase is planned to be operational in 2005. In Figure 3-11 the capacity is given compared to three throughput growth scenarios.

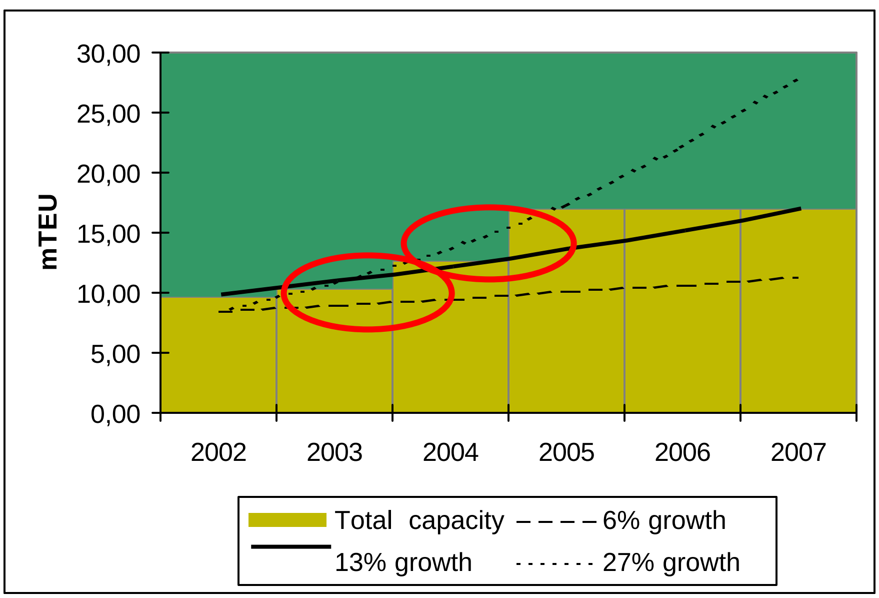


Figure 3-7 ***Addition of capacity of Yangshan phase 1 in 2005***

For the growth scenarios of 6% and 13% Yangshan can offer a solution. However, from this figure can also be seen that the growth scenario of 27% is exceeding the capacity at the beginning of 2003. Only at the beginning of 2004 and 2005 the capacity is suitable.

When the construction of the port is delayed and Yangshan becomes operational later than initially planned the consequences are even stronger as can be seen from Figure 3-12.

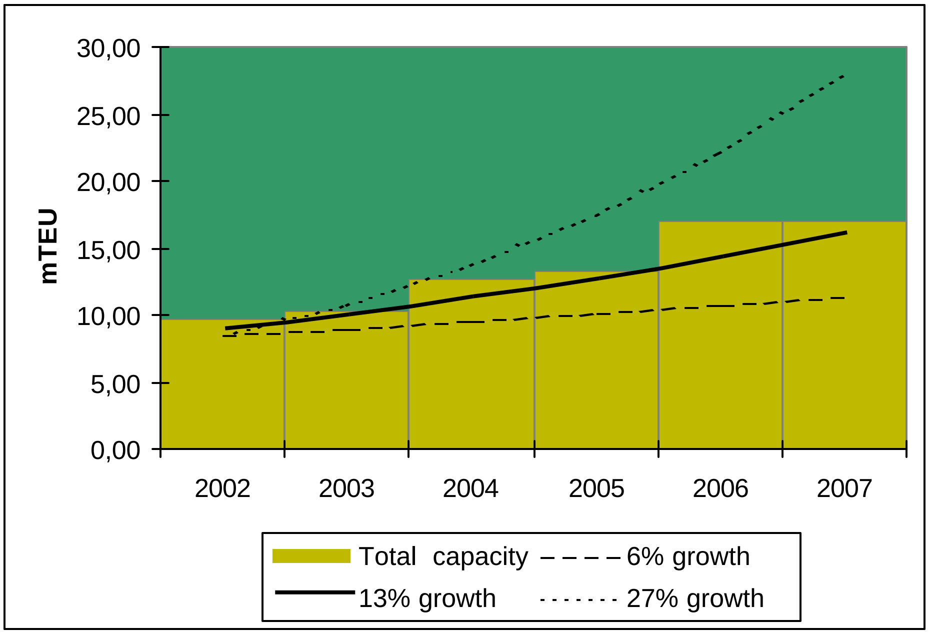


Figure 3-8 ***Addition of capacity of Yangshan phase 1 in 2006***

Even when the construction is delayed with one year the growth scenarios of 13% and 6% are not causing problems. The throughput growth scenario of 27% however is only reached at the beginning of 2004. With the current annual throughput growth being about 30% the latter scenario is the most likely to occur.

It must be noted that in the given figures 3-11 and 3-12 the design capacities of the terminals are used, except for the already existing terminals of Shanghai. For these terminals the effective capacity is used. This might make it possible for the ports to diminish the gap between the throughput and the capacity by produce above their design capacity. However, the figures learn that the creation of extra capacity is necessary to a high degree.

3.6. Conclusions

- Shanghai strongly exceeds the average worldwide growth in container throughput (5-year average annual growth until 2002: +28% for Shanghai versus +8.6% worldwide).

- The great impact of Shanghai on the Chinese trade has given the capacity development of the port a high priority with the Chinese government.

- Competition between the ports mainly focuses on the contestable hinterland and the contestable port destinations. Attractiveness of a port for liner companies plays a crucial role: good location in combination with good facilities and service will make liners decide to have their (transshipment) calls done at such port. To attract more, and especially the larger vessels, sustained growth is essential to the port of Shanghai.

- The current total design capacity of Shanghai is 3.6 mTEU, at the end of 2005 the total design capacity will have grown to 6.2 mTEU. Actual throughput in 2002 was already 8.6 mTEU (released by Shanghai port). Since 1998, actual throughput has been exceeding design capacity due to high port efficiencies and double counting of transshipment moves. Adjusting for the double counting learns that only from 2000 onwards throughput exceeds the design capacity. In 2003 Shanghai will have stretched its throughput capacity to the maximum, whereas only very limited backup might come from Ningbo port.

- Shanghai is suffering from depth restrictions. The rather shallow navigation channel that forms the connections between the port and the sea causes this. With the absence of other deep-water locations near Shanghai, the seagoing navigation is forced to use the estuary of the Yangtze River to enter the port.

- If Shanghai wants to keep up with the throughput growth, which is of major importance for its international position, it also needs to keep up with the increasing vessel sizes.

- The depth restriction of the river mouth is caused by the natural conditions of the river and the high sediment flow from the Yangtze River. The South branch (North passage) of the estuary is the main passage for run-off and navigation. Here regulation works started in 1998 to confine and control the current and to increase the sediment carrying capability of the passage. Thanks to continuous maintenance dredging (Phase 1), the depth of the navigation channel currently is 8.5 meters below chart datum.

Phase 2 and 3 of the dredging programme aim to deepen the channel to CD-10m and CD-12.5m respectively.

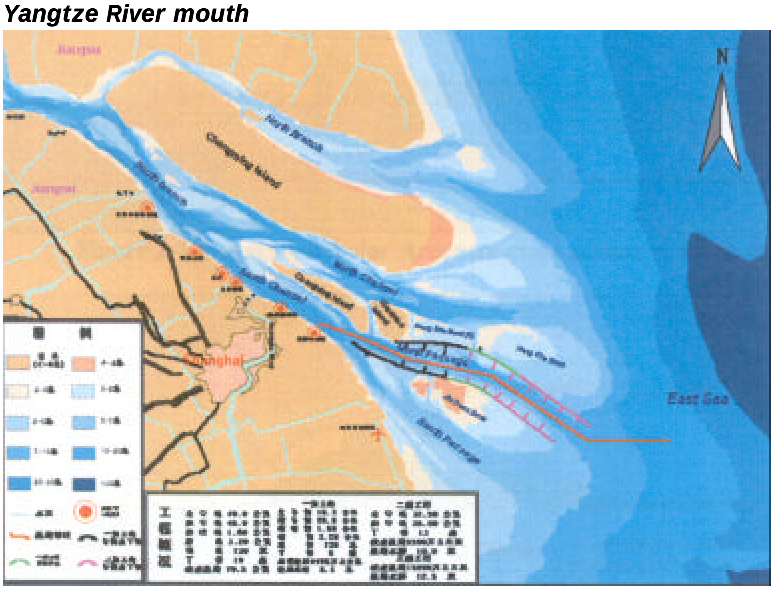
- An investigation should be made into the consequences of the construction of the regulation works on the discharge per passage

- The dredging programme should allow the new largest vessels to call at Shanghai. Depending on the depth of the entrance channel and the tidal influences, the maximum permissible draught of a vessel can be determined per dredging phase.

- Although phase 2 of the dredging programme was planned to start in 2001, this has not yet happened. Rumours indicate that the planning is adjusted to the construction plans of Yangshan Port. Not only is apparently all dredging equipment needed at Yangshan, also the political priority for the moment seems to be at Yangshan Port.

- The construction of Yangshan Container Port offers extra capacity to the capacity of Shanghai Port. It is estimated that a delay of one year of the construction causes a gap between the capacity of the port and the throughput when this is annually increasing with 27%.

Yangtze River mouth



4. Assessment of the hinterland network of Shanghai for future traffic absorption

From the previous chapter it becomes clear that Shanghai is facing various problems. Yangshan Port should bring the solution for the capacity problems and the lack of deepwater berths of Shanghai. However, the extra containers from Yangshan will be using the same hinterland connections as the containers coming from Shanghai. In this chapter the pressure on the hinterland connections and the capability of the current transport network shall be determined.

4.1. Determination of the modal split of Shanghai and Yangshan Port

As a transport node, the port of Shanghai connects several modalities: road transport, rail transport and transport via inland waterways with the ocean. Interaction of these modalities brings about a lot of cargo loading and unloading activities. The handling of cargo can be divided into three categories according to the used trade and shipping services:

- Ocean-international services or Far Sea services
- Short-sea international services or Near Sea services
- Domestic services

The latter, the domestic services can be divided into:

- Coastal-domestic services
- River domestic services
- Road services
- Rail services

The Far sea services mainly go to the USA and Europe while the Near Sea services for the most part serve Japan, Korea and South-east Asia, as shown in chapter 2. The coastal domestic services are responsible for places along China's coastline and the river domestic services see to destinations along the Yangtze River.

Also important is the division into transshipment and non-transshipment cargo. The difference lies in the fact that non-transshipment cargo needs to be transported to or from the hinterland and directly transhipped cargo does not. Non-transshipment cargo therefore needs to use the hinterland transportation modalities.

The pressure on hinterland connections is mainly determined by the modal split of both Shanghai and Yangshan port and the resulting total container volume per modality.

4.1.1. Modal Split of Shanghai Port

Recent modal split figures of Shanghai are not available. Separate prognoses for the transport of *international* containers and *domestic* containers on the other hand can be retained from the Masterplan [29]. To determine the actual modal spit of Shanghai a combination of these prognoses has to be made. International containers are containers with an international origin *or* destination while domestic containers have a domestic origin *and* destinations.

The prognoses for international and domestic container transport provide figures for the years 2000 and 2010. The interfacing figures are assumed to have a linear correlation. In Table 4-1 expectancies for the modal split of the international containers are given. In Table 4-2 the modal split expectancies for the domestic containers are given.

Year	Rail (%)	Highway (%)	Waterway (%)	Total (%) International
2000	6.00	41.00	53.00	100.00
2002	7.75	43.75	48.50	100.00
2005	9.50	46.50	44.00	100.00
2007	11.25	49.25	39.50	100.00
2010	13.00	52.00	35.00	100.00

Source masterplan [20]

Table 4-1 Modal split expectancy for hinterland transport of International containers

Year	Rail (%)	Highway (%)	Waterway (%)	Total (%) Domestic
2000	8.59	75.92	15.49	100.00
2002	8.30	76.60	15.10	100.00
2005	8.00	77.30	14.70	100.00
2007	7.80	78.00	14.20	100.00
2010	7.51	78.67	13.82	100.00

Source Masterplan [20]

Table 4-2 Modal split expectancy for hinterland transport of Domestic containers

Combining the domestic and international containers in the right proportion gives the modal split of Shanghai Port. The ratio between international and domestic containers will vary over time: The construction of Yangshan port (and the resulting attraction of international freight in the area) will probably also cause an increase in international containers at Shanghai port. On the other hand, the growing economy might increase the number of domestic containers as well. The share of the international and domestic containers, as expected by the Chinese Water Design Institute, to the total throughput in percentages is given in Table 4-3.

	International (%)	Domestic (%)
1998	82	18
2000	80	20
2002	85	15
2005	91	9
2007	90	10
2010	89	11

Source Chinese water Design Institute

Table 4-3 Proportion of international containers to the total throughput

When the ratio of international and domestic containers is applied to the modal split expectancies of Table 4-1 and Table 4-2 the modal split of the port of Shanghai is found. For example, in 2000 the proportion of international containers transported by rail was 6%. Of the domestic containers 8.59% was transported by rail. The ratio of international and domestic containers in 2000 was 80:20. Therefore the assumed proportion of railway transport of Shanghai Port in 2000 is 0.80*6% + 0.20* 8.59% = 6.52%. This can be found in Table 4-4. Further calculations will be based on these assumed prognoses for the modal split of Shanghai Port.

Year	Rail (%)	Highway (%)	Waterways (%)	Total
2000	6.52	47.98	45.50	100
2002	7.83	48.68	43.49	100
2005	9.37	49.27	41.36	100
2007	10.91	52.13	36.97	100
2010	12.40	54.93	32.67	100

Table 4-4 Prognoses for the modal split of Shanghai Port

Now the modal split is calculated, the total container volume for each year in the prognosis can be determined. Therefore, the total throughput of Shanghai Port and the transshipment incidence are also needed. The latter is necessary to determine the actual throughput having the hinterland of the port as destination. As explained in the previous chapter the current transshipment incidence of Shanghai Port is 0.4. Based on this chapter the transshipment incidence is not likely to change much in the near future and will therefore be also 0.4. When the modal split forecast, given in Table 4-4, is applied to the throughput forecast, the *maximum* pressure on the hinterland transport network caused by the port of Shanghai can be examined. The throughput figures in Table 4-5 come from the Chinese prognoses. With the transshipment incidence the actual expected pressure on the hinterland is calculated. In the table below the container volume per modality is given.

Year	Total Throughput mTEU	Hinterland mTEU	Rail mTEU	Highway mTEU	Waterway mTEU
2000	5,61	3,37	0,219	1,615	1,531
2002	8,61	5,17	0,405	2,515	2,247
2005	9,90	5,94	0,556	2,927	2,457
2007	10,00	6,00	0,654	3,128	2,218
2010	10,10	6,06	0,751	3,329	1,980

Table 4-5 Container volume per modality of Shanghai Port

From the table can be seen that after 2005 the expected throughput is not changing very much anymore. This is caused by the reached maximum capacity of the port according to the previous chapter. However, the pressure on highways will continue to increase while the pressure on the waterways will diminish. Railway usage will also increase over time.

4.1.2. Modal split of Yangshan Port

When the Port of Yangshan becomes operational, containers coming from Yangshan need to use the same hinterland connections as containers coming from Shanghai. To determine the total pressure on the modalities also the expected modal split and container volume of Yangshan Port are required.

From the overall Plan of Yangshan Deepwater Port Area of Shanghai International Shipping Centre (Jan 2003) prognoses of the modal split of the new port at Yangshan are retained. The prognoses were made by the Chinese Water Design Institute. The deduction of these figures to obtain the modal split of Yangshan Port is given in the appendix 6. The results and the interpretation are given below (Table 4-6).

Modal Split (%)	2005	2007	2010	2015	2020
Highway	67.1	72.5	71.4	70,9	70
Rail	6.6	5.1	4.1	4,6	5.2
Yangtze River	6.6	10.3	13.3	14.6	16.2
Coastal domestic	19.7	12.1	11.2	9.9	8.6
Total	100	100	100	100	100

Table 4-6 Modal split of Yangshan port 2005 to 2020

From this table can be seen that highway usage is increasing until 2007 and afterwards slowly diminishing. The trend for railway transport is the other way around, first decreasing and after 2015 increasing. Transport by the Yangtze River is constantly increasing while usage of coastal domestic services is constantly diminishing. In Figure 4-1 the changes in the modal split of Yangshan Port are given for all years of the prognoses in a graph. It can be seen that over time the use of road and coastal domestic services will diminish in favour of transport over the Yangtze River and rail services.

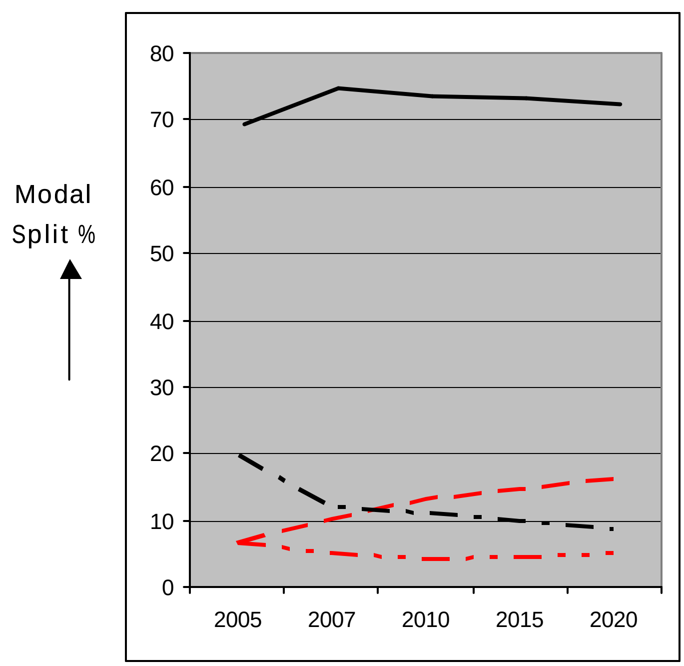


Figure 4-1 Contribution of the different modes to total transport handling for Yangshan

When the figures from the modal split are converted into growth figures, it can clearly be seen that transport over the Yangtze River is the only transportation mode with a constant positive growth over the period 2005-2020. Rail transport shows a positive growth during the second part of the same period.

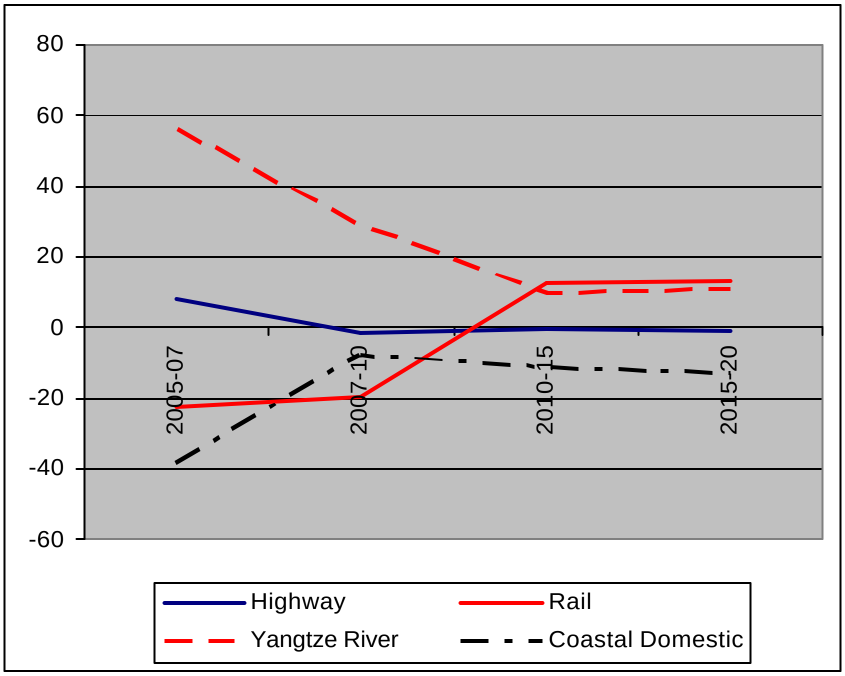


Figure 4-2 Growth of the hinterland modalities for Yangshan (2005-2020)

With the modal split available also the actual container volumes can be determined. These are given in Table 4-7.

Yangshan Port, total flows					Unit:10^3TEU
Year	**2005**	**2007**	**2010**	**2015**	**2020**
Total throughput	**2,200**	**4,000**	**6,700**	**10,300**	**14,300**
Total Transshipment	680	1,090	1,800	2,750	3,800
Total distributed volume	**1,520**	**2,910**	**4,900**	**7,550**	**10,500**
Of which					
Chinese Coast	300	352	549	748	903
Yangtze River	100	300	652	1,102	1,701
Railway	100	148	200	347	546
Highway	1,020	2,110	3,499	5,353	7,350

Table 4-7 Total container volume per modality

According to the Chinese Water Design Institute 48% of the throughput will be import and 52% will be export.

From the figures in the tables above also the *transshipment incidence* at Yangshan can be determined for all years in the prognoses. The total transshipment as a percentage of the total throughput gives the transshipment incidence. The calculation for the year 2005 is as following: According to Table 4-7 the total transshipment of 2005 is 680,000 TEU, the total throughput is 2,200,000 TEU. For 2005 the transshipment incidence is (680,000/2,200,000 =) 0.31. All other years in the prognoses have a transshipment incidence of 0.27.

4.1.3. Conclusions regarding the modal split

To determine the pressure on the hinterland connections, the modal split of both Shanghai and Yangshan are of importance. Because prognoses of Shanghai's modal split are only available until 2010, the total container volume per modality is presented until this year. Numbers given in Table 4-8 for waterway usage include coastal transport and transport over the Yangzte River.

Year	Rail mTEU	Highway mTEU	Waterway mTEU
Shanghai			
2002	0,405	2,515	2,247
2005	0,556	2,927	2,457
2010	0,751	3,329	1,980
Yangshan			
2002	0,00	0,00	0,00
2005	0,10	1,02	0,40
2010	0,20	3,50	1,20
Total			
2002	0,405	2,515	2,247
2005	0,656	3,947	2,857
2010	0,951	6,829	3,180

Table 4-8 Total container volume per modality

From the table can be seen that in 2005 rail services and highway are expected to have difficulties in keeping up with the growth because the figures are multiplied with a factor 1.5 compared to 2002. The current railroad utilisation is already high according to section 4.2.2. In 2010 also water transport will have increased tremendously compared to 2002.

In fact, the construction of Yangshan Port will put extra pressure on all hinterland connections. The unavoidable question is therefore whether the transport network will be able to cope with the expected transport volume growth.

4.2. Capability of the Chinese Transport Network

The port of Shanghai is connected to inland provinces by rail, road and inland waterways. The current state of the transport network in the Yangtze River area is well-developed compared to other parts of China and is still improving. Other provinces lag behind with the development of their transport network. Maps of the transport network can be found in appendix 7.

Since China has been reforming its economy over the last two decades, more and more foreign corporations have been setting up business like manufacturing and sales divisions. To be able to maintain the advantage in the competitive position by being situated in low-cost China, a smooth and efficient supply chain must be available.

Ta, Choo and Sum (2000)[1] state:

> *While China presents a huge potential and attractive 'low cost environment' for foreign firms and investors, it may still be unprofitable if there are serious problems in getting the products to the customers on time and in good condition. An underdeveloped transport infrastructure, therefore, can pose a serious obstacle to a large country like China that is in transition to a market economy and requires foreign investments.*

This statement is supported by a survey of over 200 United States exporters to China. This survey claimed that poor performance of local suppliers and carriers in China are basic concerns and create significant barriers to international operations. (Carter et al, 1997).

According to the above survey and statement it is clear that the infrastructural network on national level could not keep up with the growth of the Chinese economy in the past period. The demand for transport of people and goods has exceeded the capacity of its road and railway systems.

Currently the Chinese infrastructure and logistical network does not develop at sufficient speed to cope with the growth in production.

[1] [18]

4.2.1. Highway

An example of the lagging behind is the highway density; with a density of around 0.04 kilometres per person, the highway density in China is less than in India and is significantly less than in Japan, the UK and the USA. However, in absolute terms, China constructed more than 230,000 kilometres of new road in the period 1994 to 1999, thereby accounting for the highest road network growth by far of all Asian countries. In 1999 the total Chinese road length was 1,352,000 kilometres and growing annually with 3.9%. Much of this growth came from the development of the long distance road network linking the country's extremities. Around 13% of the total road length is found in the Yangtze River Area; 8% is national trunk road, 20% is provincial road and the other 72% is county and rural road[2]. The conditions of highways in Shanghai and Jiangsu are comparatively good.

In recent years road links like Shanghai-Ningbo and Shanghai-Nanjing have been greatly improved. Also the expressways from Yichang to Wuhan in Hubei, from Nanchang to Jiujiang in Jiangxi, from Wuhan to Jiujiang and from Hefei to Wuhu in Anhui are fully in use for container transport. The highway networks in the provinces Hubei and Jiangxi are sometimes of low standard and therefore lagging behind. Most of the highway terminals are situated around the medium and large cities and ports.

4.2.2. Rail

From 1994 to 1999 the expansion of the rail network in China was considerable. China has been investing in both network expansion (the total length of railways in operation increased with 8.6% during this period) as well as electrification of railway networks as can be seen from Table 4-9. This process is still continuing.

	1990	1995	2000	2001
Length of Railways in Operation (km)	53,378	54,616	58,656	59,079
Double-Tracking Length (km)	13,024	16,909	21,408	22,640
Percentage of Total Length (%)	24.4	31.0	36.5	38.3
Length of Electrified Railways (km)	6,941	9,703	14,864	16,877
Percentage of Total Length (%)	13.0	17.8	25.3	28.6
Length of Diesel Engine Routes (km)	16,097	24,749	39,497	40,466
Percentage of Total Length (%)	30.2	45.3	67.3	68.5

Table 4-9 Development of the Railway network

[2] [29]

In reaction to this railway expansion both the locomotive fleet and wagon fleet also expanded with 8% and 17% respectively.

All major cities in China are connected via the railway network. The rail improvements reduce the transport time. The opening of the Shanghai-Kowloon railway for example shortened the travel time from Hong Kong to Shanghai to 29 hours.

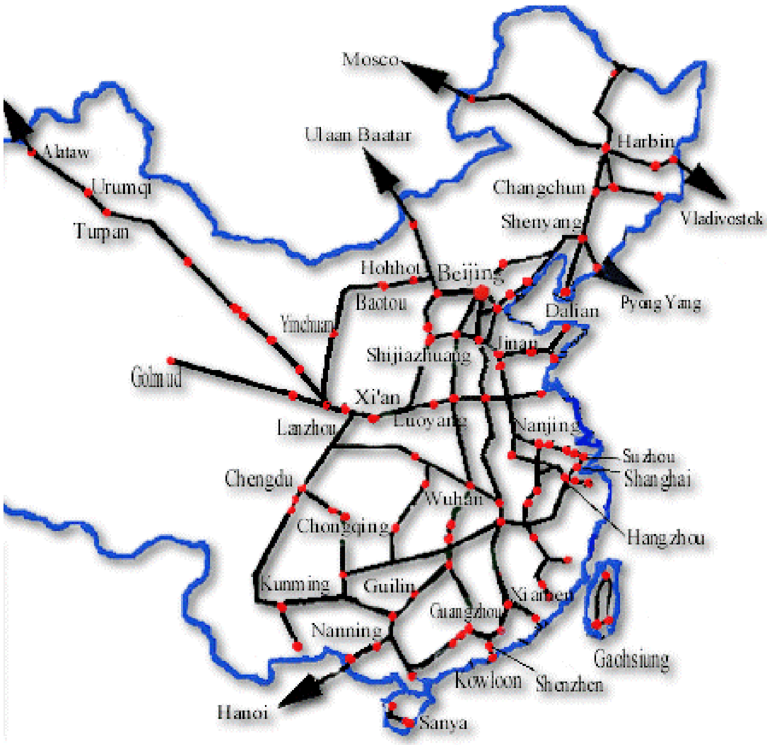


Figure 4 - 3 Rail network in China

14% of total length of railways in operations is found in the Yangtze River area, while this area covers only 6% of total national surface. Furthermore, the proportion of double track railways is higher here than nationally; 70% of the rail track in this area is double tracked.

In 1995 the Yangtze River area counted 23 railway terminals with the capability to handle 20 feet containers. 15 of these can also handle 40 feet containers. Four terminals are located in Shanghai, 9 in Jiangsu, 5 in Anhui, 1 in Jiangxi and 4 in Hubei.

Even though efforts to expand the railway network were considerable in the past period, traffic volume did not really grow as much. Nevertheless, the Chinese Railways achieved a higher route productivity by far of any other country in the Asian region. China's railway system has been among the most intensively utilised in the world.

4.2.3. Waterways

Improvements should also be made for the ports and shipping infrastructure of China, which is subscribed by the World Bank[3]. Of the country's 60 major coastal ports, only 446 of a total of 1,322 berths are deepwater (China Statistics, 2000). Compared to other Asian countries however, China has a well-developed inland waterway transport with an inland waterway system comprising more than 5,600 navigable rivers and a total navigable length of 116,500 km. Of the navigable rivers, 210 inland rivers (3.75% of the total) are found near and around Shanghai. These rivers have a total navigable distance of 2,100 kilometres. A large proportion of China's navigable waterways is located within the courses of main rivers like the Yangtze River (total length is 73,000 kilometres), the Pearl River (total length is 13,000 kilometres), Huaihe River and the Helongjiang River (total length is 4,700 kilometres).

The Yangtze River is the main waterway for container transport from Shanghai Port. Its navigable length is 57,447 kilometres, accounting for 52.6% of all inland rivers in China. Container transport was initiated in the Yangtze River area in the year 1981. From then onwards the construction of ports and water works along the Yangtze River and other inland waterways took off. The majority of navigation channels are concentrated in the middle and lower reaches of the river. Adding up all navigable kilometres, the provinces of the Yangtze River area have a total of 45,537 navigable kilometres which account for 77.2% of all navigable kilometres of the Yangtze River. Downstream of Nanjing the density of the navigation channel network is distinctly higher than upstream.

Besides the Yangtze River, the area also has other inland rivers and navigational channels like the Han River, Gan River, Hefei and Yuxikou channel, the Huai River and the Grand Canal. The Grand Canal has a total length of 1,044 kilometres, runs north-south, and is crucial for connecting the Yangtze River valley, the Yellow River valley and secondary river systems. Currently about 200 inland ports, including 85 leading ports, are found along these waterways. The waterway network contains about 900 navigational structures such as ship-locks and ship-lifts. Among these, the largest five-step ship-lock of the world is found, with dimensions of 280x34x5 metres, located at the Three Gorges Dam near Jiujiang.

More information about the navigability of the Yangtze River is found in Chapter 8.

[3] [38]

4.2.4. Conclusions from the current transport network

As the Yangtze River is one of the main corridors to push the Chinese economy from the coastal area to the hinterland, the transport development of the Yangtze River area will be given high priority. This is supported by the Go-West policy of the Chinese government. This is already proven by the fact that the Yangtze River area has a transport network that is of a higher level than the average national transport network. 13% of the highway network, 14% of the railway network and almost 53% of the waterway network are located in the Yangtze River area, although the area only covers 6% of China. This can be explained by the fact that the Yangtze River area is the economic core of China.

> With transportation infrastructure being one of the major facilitators for trade, efficient transport modes and development of logistic systems for the Yangtze River area are essential. Also, the success of China's "Go-West" policy (Chapter 2) is dependant on the inland infrastructure.

Even though China has plans to improve its transport infrastructure, the World Bank estimates that it will not be able to meet its transport requirements until at least the year 2020. As long as the issues of the transport network still exist, the importance of efficient usage of the available facilities in and capacities of the port of Shanghai and the port of Yangshan is even greater.

4.3. Combinations of transport modes

Transport modes are often combined. The combination of modes is indicated as 'inter-modal' transport and is of great importance for the competitive position of a port. Also for transportation chains ports are of major importance, as these are the vital link in the chain. In the case of Yangshan, there are various transport options over water. In this paragraph insight in both these aspects will be given for the situation in China.

4.3.1. Inter-modal transport in China

For container transport from Shanghai and Yangshan mostly combinations of different modalities will be used. A definition[4] of inter-modal transport is

[4] [27]

"The movements of goods in one loading unit, which uses successively several modes of transport without handling of the goods themselves in transshipment between the modes"

This definition implies three conditions[5]:

- Two or more different transport modes are deployed.
- The goods remain in one and the same transport loading unit for the entire journey, and (less direct from the above definition):
- When inter-modal transport is using rail or water, it effectively replaces potential long distance transport by road.

The integration of various transportation modes and the realisation of an efficient transport organisation provide a shipper a rapid, economic and reliable transport service. According to the Masterplan Study Report [29], inter-modal transport has good economic returns and social effect because it effectively reduces the social costs of transport such as road congestion, environmental pollution and traffic accidents by making full use of the inland waterway and railway transport and realises sustainable development of communications and transport.

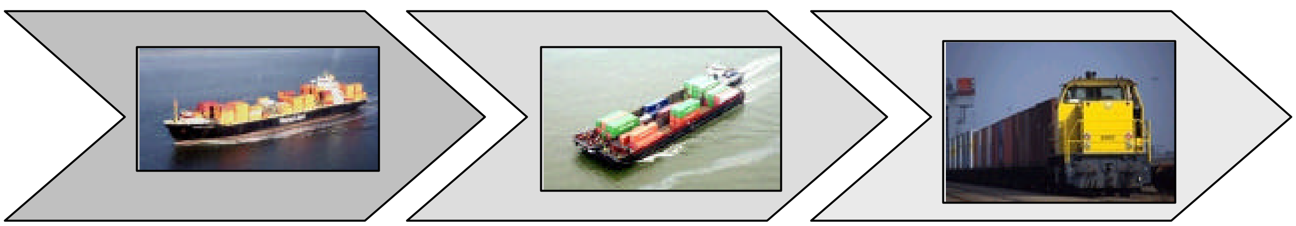


Figure 4-4 Inter-modal transport

In an ideal effective inter-modal system the used transportation chain should be as far reaching as possible. The ship, rail and road connections should be coordinated at the port and inland terminals under a single door-to-door freight bill.

According to the abovementioned definition of inter-modal transport, the transportation of containers from the Port of Shanghai and the Port of Yangshan to the final destination in the hinterland will most likely be inter-modal transport. But the conditions in China are currently not creating the ideal inter-modal transportation chain. Especially when it comes to the organisation and planning of the process a lot of progress can be made.

Currently China is not maximally prepared for the use of inter-modal transport while the potential of inter-modal transport is tremendous.

[5] [27]

4.3.2. Possible water transportation modes

Beside the usage of rail and road transport the location of Yangshan Port and Shanghai Port can use several ways of water transport, with the Port of Yangshan lying 30 kilometres offshore and the Port of Shanghai lying at the mouth of the Yangtze River. For this reason transport over water should be further specified. Often inland shipping by inland navigation vessels or river barges is used for hinterland transport over water. However, in the situation of Yangshan and Shanghai there are also possibilities to transport containers by so-called *sea-river transport*.

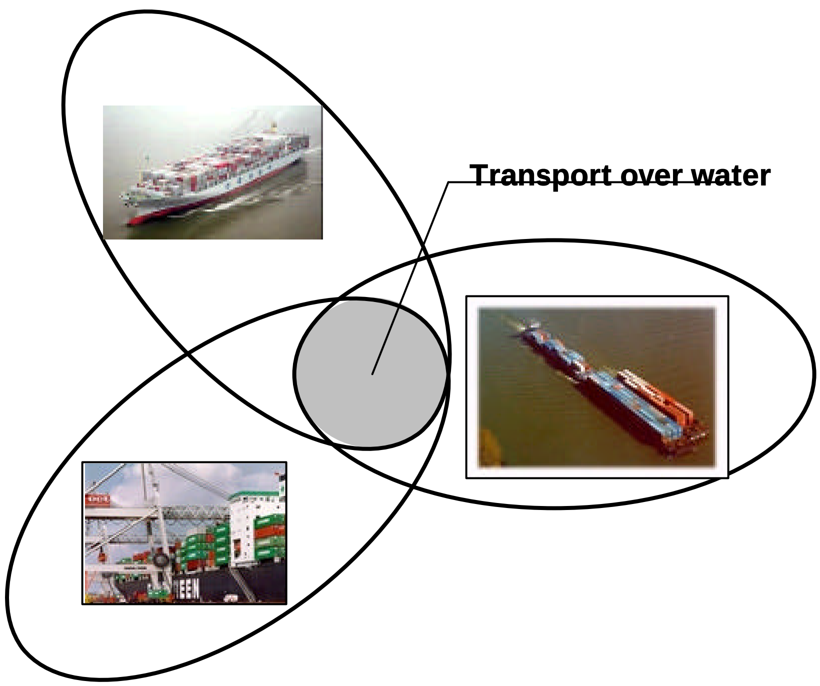


Figure 4-5 Competition of water transport

Using sea-river transport means sea transport and river transport are combined by using one vessel, a sea-river vessel. The water level of the river is for the most part determining the navigable length on the river. Sometimes partially loading of the vessels can offer a solution for limited depths of the river. In the case of Yangshan Port, the main reason to examine the sea-river transport option is the fact that container transport is already forced to cross a sea section and also has the option to use the wide Yangtze River for further transport.

This combination makes the sea-river option even more reliable. An advantage of sea-river transport for containers is the fact that the container movements are reduced, by minimising the amount of transshipments. Another advantage is that areas that had no direct access to the sea can now be reached directly.

The sea-river vessels can be used in four different ways:

1) link between two production units
2) regularly scheduled link
3) feeder for large scale trading lines
4) tramping

The standardised dimensions of a European sea-river vessel are a length of 82 metres, a beam of 11.4 metres and a water draft of 3 metres. sea- river navigation allows goods to be transferred from rail or road transport to transport over water, thereby combating environmental problems.

4.4. Conclusions regarding the traffic absorption

- It is the Chinese intention to solve the capacity problem and lack of deepwater berths of Shanghai largely with the construction of Yangshan port. The extra containers coming from Yangshan will use the same hinterland connections as those from Shanghai. Therefore the pressure on the various hinterland modalities should be determined by combining modal split and throughput prognoses from both ports.

- Various sources have been used to calculate future pressure on the hinterland. For example for Shanghai Port only separate prognoses of the modal split are available (divided into domestic and international flows). Taking into account the forecasted split between domestic/international flows, Shanghai's transshipment incidence and the forecasted throughput of Shanghai Port, the projected container volume per modality was calculated. Similar calculations have been done for Yangshan.

- Total container-volume attributable to Shanghai and Yangshan Port, which needs to be transported via the hinterland, will grow from 5.17 mTEU in 2002 to 10.96 mTEU in 2010.

- From the modal split calculations can be seen that in 2005 rail services and highway are expected to have difficulties in keeping up with the growth because the volumes are increased by factor 1.5 compared to 2002. The current railroad utilisation is already high compared to other countries. In 2010 also water transport (including coastal transport and transport over the Yangtze River) will have increased significantly compared to 2002; from 2.247 mTEU to 3.180 mTEU.

- Despite continued investments in highways, rail and shipping infrastructure, the Chinese infrastructure and logistical network does not develop at sufficient speed to cope with the growth in production. An example of the lagging behind is the highway density; with a density of around 0.04 kilometres per person, the highway density in China is less than in India and is significantly less than in Japan, UK and the USA.

- Compared to other Asian countries however, China has a well-developed inland waterway transport with a system comprising more than 5,600 navigable rivers and a total navigable length of 116,500 km.

- The Yangtze River is the main waterway for container transport from Shanghai Port. Its navigational length is 57,447 km, accounting for 52.6% of all inland rivers in China. From 1981 onwards the construction of ports and water works along the Yangtze River and other inland waterways took off. Downstream of Nanjing the density of the navigation channel network is distinctly higher than upstream.

- With transportation infrastructure being one of the major facilitators for trade, efficient transport modes and development of logistic systems for the Yangtze River area are essential. The success of China's 'Go-West' policy is dependant on the inland infrastructure.

- Currently China is not maximally prepared for the use of inter-modal transport while the potential of inter-modal transport is tremendous.

- In the case of Yangshan Port, the main reason to examine the 'sea-river' transport option is the fact that container transport is already forced to cross a sea section and also has the option to use the wide Yangtze River for further transport. An advantage of sea-river transport for containers is the fact that the container movements are reduced, by minimising the number of transshipments. This also improves reliability. Furthermore, sea-river transport allows goods to be transferred from rail or road to transport over water which is more environmental friendly.

5. Transportation Chains between Ports and Hinterland destination

A good transport network is of great importance for China. Therefore this chapter examines the various options for transporting containers from both ports to the hinterland. The transport of containers knows several phases. Distinction is made between main haulage and pre- and post haulage. For Shanghai Port and Yangshan Port eight options for hinterland transport are given in this chapter.

5.1. Transportation Chains between Ports and Hinterland

The base of container transport is the existence of a shipper and a customer. Both are found in every transportation chain. For most transportation chains the minimum number of terminals is two and a distinction between pre-/on carriage and main transport can be made. This is shown in the flowchart of Figure 5-1. Main transport is the transportation process between the two terminals and does not necessarily consist of a non-stop transport from one terminal to the other. A more detailed description of the terminal processes is found in appendix 8.

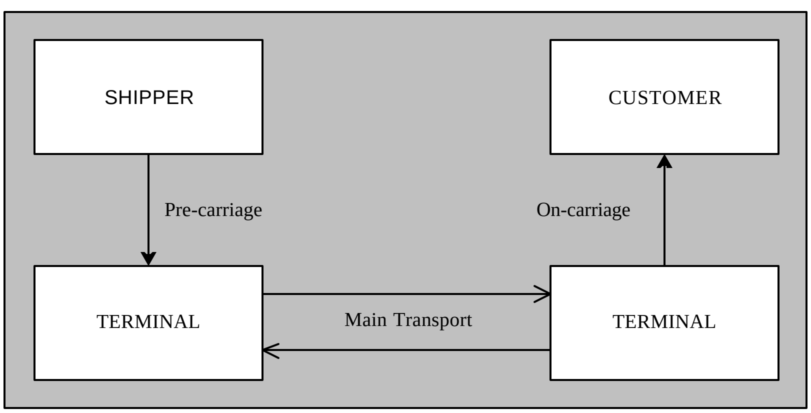


Figure 5-1 Transportation Chain

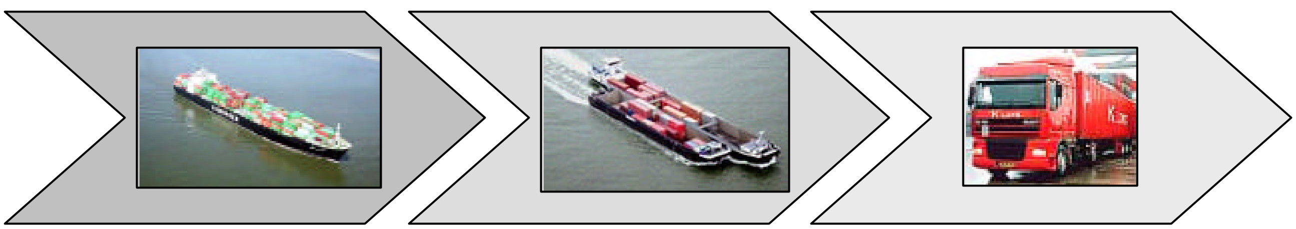
This main transportation chain can be extended with transfers at other terminals, possibly towards other foreland modes such as rail or road. These can be integrated in this main transport. Pre- and on-carriage takes care of the haulage to or from the shipper and the customer. All transportation segments combined (incl. pre-/post haulage) form an "inter-modal" transportation chain, as described in the previous Chapter.

When assessing the situation at Shanghai Port and Yangshan Port, the deep-sea transport bringing containers to and from these two ports can be pointed out as the main transport. The transportation of containers from Shanghai and Yangshan towards and through the hinterland, and vice versa, is therefore essentially pre- and post haulage using various transportation modalities and transfer points.

5.2. Transport Options for Hinterland Transport

5.2.1. Introduction to the transport options

To realise the pre- and post haulage between Shanghai Port and Yangshan Port on one side and the hinterland on the other side, several options and combinations are available.



The modalities to be considered are (in conjunction with section 4.3):

- Road transport
- Rail transport
- Inland navigation
- Short-sea transport
- Sea-river transport

The pre-/post haulage transportation chain can be divided into sections. These sections start at a terminal or origin and end at another terminal or the final destination of a container. Please note; in this case a terminal is not by definition a vessel terminal, it can also point to a road or rail terminal. The sections to be considered in this modality study for Yangshan Port and Shanghai Port are determined by the choice/selection of the most likely terminals. Obviously the terminals of Yangshan and Shanghai are included. Other terminals that will play an important role in the analysis are the terminals at Luchao Harbour which are connected via the bridge with Yangshan Port and one of the inland waterway terminals.

The sections of the transportation chain are located between:

- Yangshan Port
- Shanghai Port
- Luchao Harbour
- Inland Waterway Terminal

The potential modalities provided earlier in this chapter can be put into action on these different sections of the transportation chain.

Various opportunities for transporting containers are found when a combination of modalities and sections is made. These form the transport options between the ports and the hinterland.

In the figure below a chart representation of the opportunities is presented. The inland waterway terminal given in the chart represents one of various possible inland waterway terminals along the Yangtze River.

To keep a good overview on the chart, only the route of the containers from Yangshan or Shanghai port *to* the hinterland is shown. When the indicated directions in the chart are turned around, the routing of the containers with destination Yangshan Port or Shanghai Port is found. In appendix 9 all transportation options are given in one figure.
From the appendix can be seen that eight routes, with a various number of used modalities, can be distinguished. The minimum number of used modalities is one, whereas the maximum number is three. The table below shows which option uses which modality.

Option	Port	First modality	Point of Transfer	Second modality	Point of Transshipment	Third modality
1	Yangshan	Road via bridge	Luchao	Road or rail	-	-
2	Yangshan	Road transport	-	-	-	-
3	Yangshan	Road via bridge	Luchao	Inland navigation	Inland terminal	Road or rail
4	Yangshan	Sea-river transport	Inland terminal	Road or rail	-	-
5	Yangshan	Short sea transport	Shanghai	Inland navigation	Inland terminal	Road or rail
6	Yangshan	Short sea transport	Shanghai	Road or rail	-	-
7	Shanghai	Inland navigation	Inland terminal	Road or rail	-	-
8	Shanghai	Road or rail	-	-	-	-

Table 5-1 Hinterland transport options

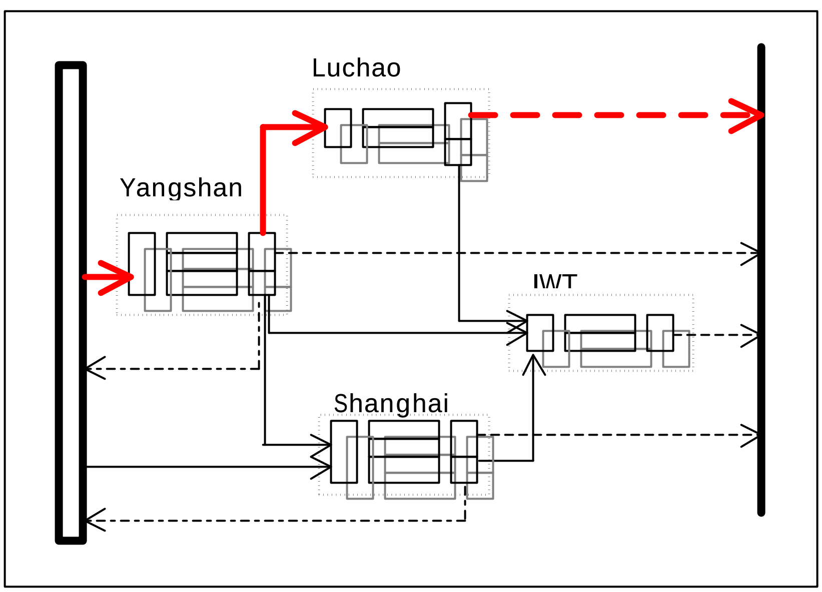
In appendix 9 on the detailed possibilities for the final hinterland transport are not given. In Table 5-1 this final hinterland transport is represented by 'Road or rail transport'.

5.2.2. Transport Options

This section outlines the eight options for the transportation of containers from the ports to the hinterland. Beside the hinterland transport in the figures also the possibility for transshipment is given. Because the possibilities for hinterland transport from both ports are investigated direct short sea transport to the inland waterway terminals is not included in these figures.

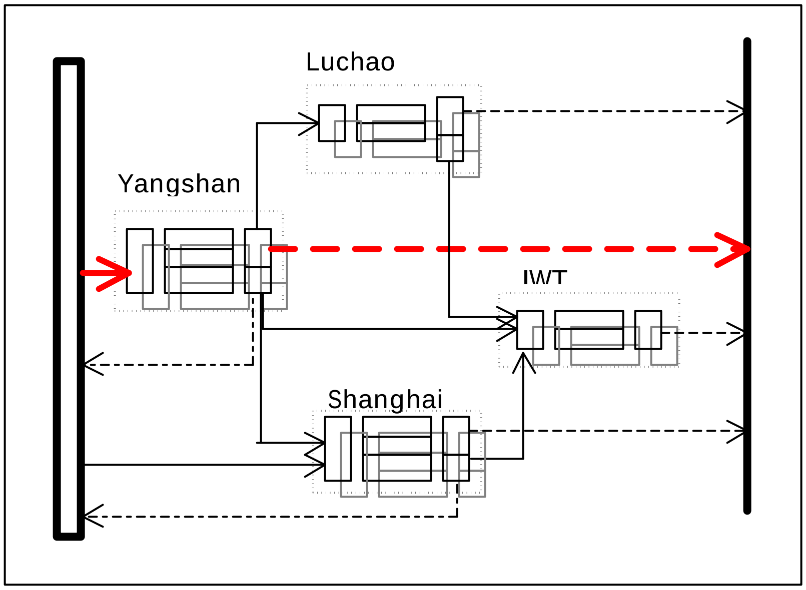
Option 1

Containers are discharged from deep-sea vessels at Yangshan Port and transported by truck via the bridge between Yangshan and Luchao Harbour City to the terminals at Luchao. In Luchao a transfer takes place towards rail or road transport.



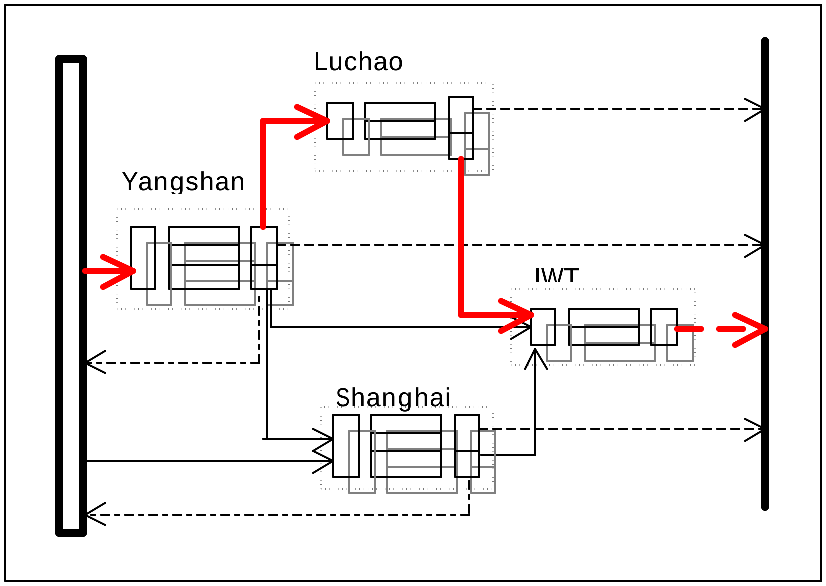
Option 2

After discharging the deep-sea vessels, the containers are further transported by truck towards their destination in the hinterland of the port. For transport towards the mainland, the bridge is used, but there is no transfer in Luchao.



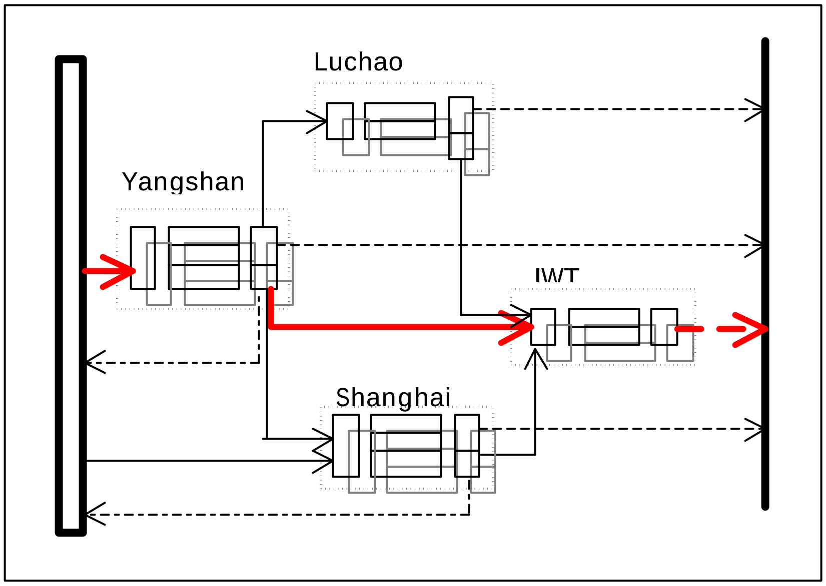
Option 3

The discharging of the deep-sea vessels takes place at Yangshan Port. After unloading, the containers are transported by truck to Luchao, via the bridge. After arrival the containers are placed on inland vessels en via the inland waterways transported to an inland waterway terminal near their final destination. If necessary rail transport will be used before a container is transported by truck to its final destination.



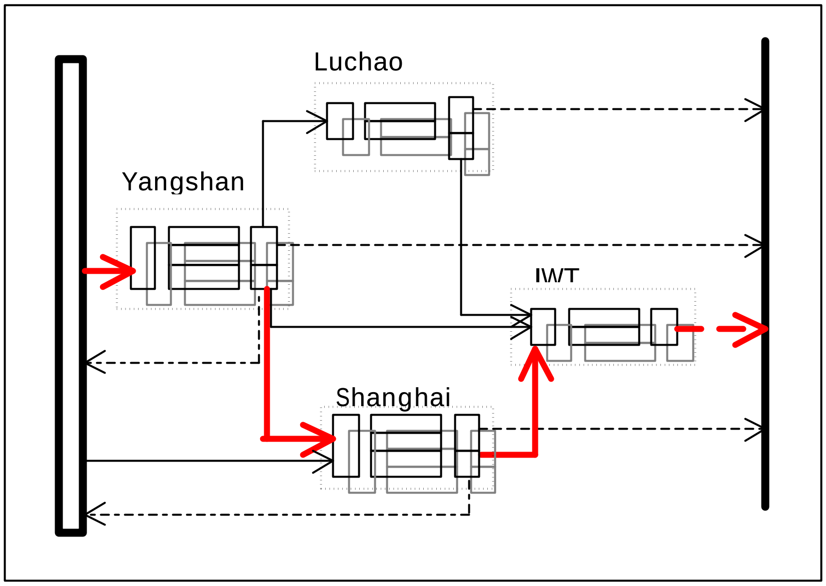
Option 4

Sea-river transport is used to transport containers arrived at Yangshan to inland waterway terminals. The depth of the vessel determines how many kilometres along the Yangtze River can be covered. After reaching the IWT, the containers will be further transported by either rail or road if necessary.



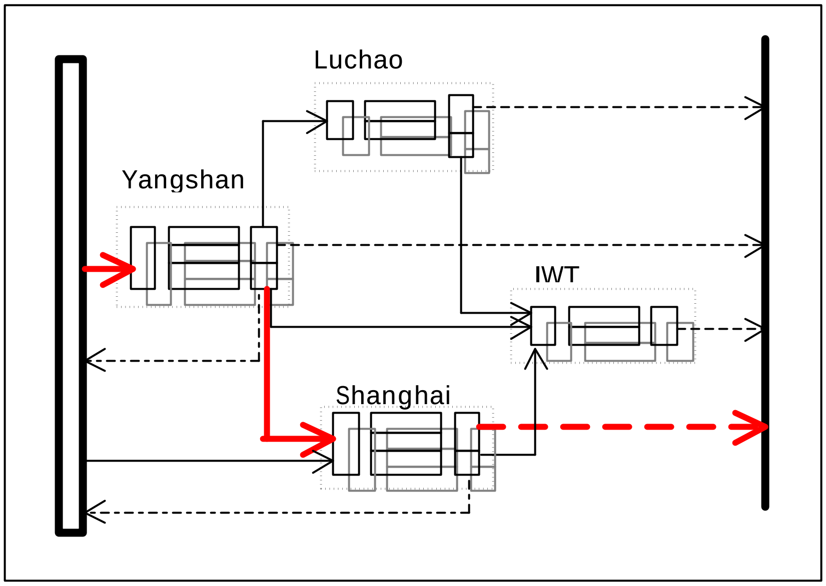
Option 5

After being discharged, containers are shipped via short sea transport to Shanghai Port where transshipment will take place. Inland vessels will be used for further transport to the inland waterway terminals. If necessary rail transport will be used, otherwise the final destination will be reached by road transport.



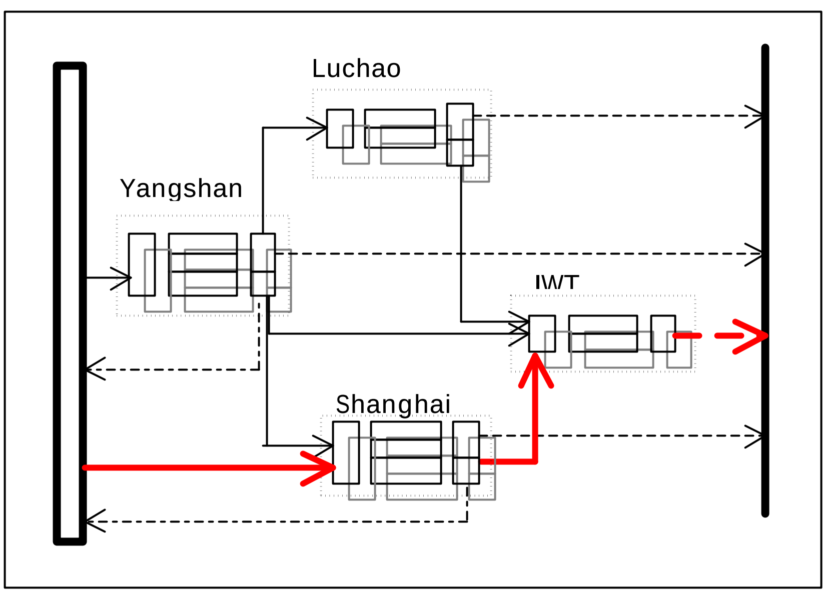
Option 6

A call will be made at Shanghai Port after unloading the containers from the deep-sea vessels. The transport between these two ports will be carried out by short sea vessels. The further hinterland transport will be done by road transport.



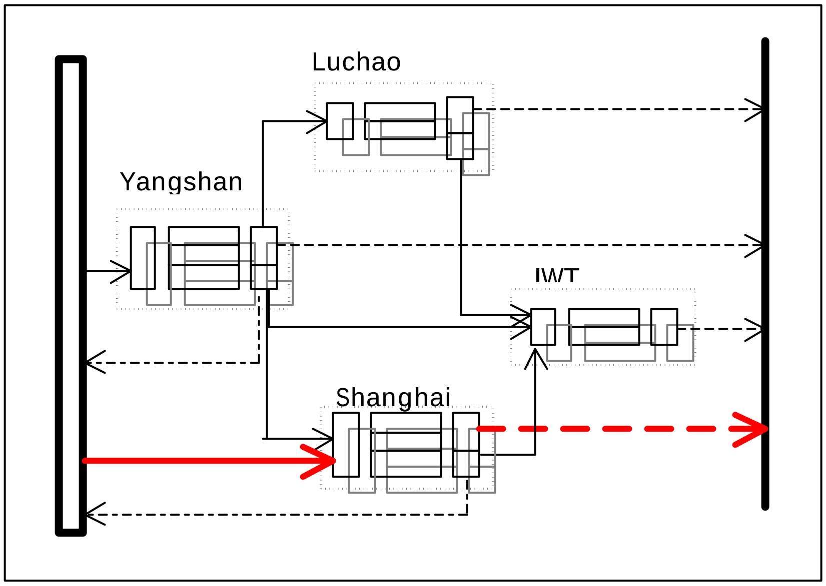
Option 7

Even though Shanghai knows a depth restriction of its entrance channel deep-sea vessels will call at Shanghai Port. They can use the tide for entering the port. From there, the containers are shipped with inland vessels to the inland waterway terminal close to their final destination. From the IWT, the containers will further be transported by rail or road transport.



Option 8

Discharging of the containers will take place at Shanghai Port. For this option also the depth restriction of the port of Shanghai should be taken into account. By truck the containers will be transported to their destination in the hinterland of the port. Currently most of the containers are transported towards the hinterland, using this transportation schedule.



5.3. Conclusions Transportation Chains

- The starting point for container transport is the existence of a shipper and a customer. Both are found in each transportation chain. For most transportation chains the minimum number of terminals is two and a distinction between pre-/on carriage and main transport can be made.

- The sections to be considered in this modality study for Yangshan Port and Shanghai Port are determined by the choice/selection of the most likely terminals. Obviously the terminals of Yangshan and Shanghai are included. Other terminals that will play an important role in the analysis are the terminals at Luchao Harbour which are connected via the bridge with Yangshan Port and one of the (various possible) Inland Waterway Terminals (IWT) along the Yangtze River.

- The five modalities to be considered are road transport, rail transport, inland navigation, short-sea transport and sea-river transport.

- When combining the various geographical sections and modalities, eight transport options between the ports and the hinterland will be found. The minimum number of used modalities is one, whereas the maximum number is three.

6. Long-term development aspects for transport in China

Of the eight transport options from the previous chapter the most favourable transport option has to be determined. As part of the determination process some important aspects of long term development should also be taken into account. Four most relevant aspects are derived from literature study[1] and discussed in this chapter:

- Transport characteristics for the transportation chains
- Infrastructural development of the hinterland
- Reliability of the transport options
- Economic potential of the hinterland

The above long term developments are obviously not the only long term developments in China but they are the most important ones in the selection process for the most suitable transport option.

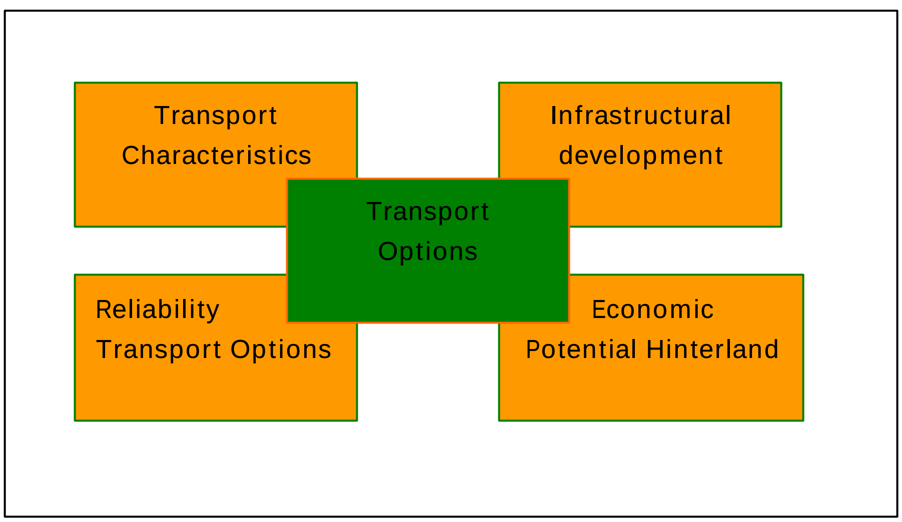


Figure 6-1 Long term development Aspects for Transportation Options

[1] [18],[19],[27],[31],[33],[37],[38]

6.1. Transport Characteristics

The transport options given in the previous chapter do not use the different transport modes in the same way. Some routes use more water transportation and less truck transportation while others use only water transportation or truck transportation for example. This different usage of the transport modes results in different transportation costs and different transportation times as truck transport for example is faster but also more expensive. More about the relation between time and costs can be found in the appendix 10 ‘time and cost approach of a transportation chain’.

Transport mode	Advantage	Disadvantage
Road transport	high service speed direct delivery to customer	relative high costs
Rail transport	relative low costs	medium service speed no direct delivery
Waterway Transport	low costs	low service speed no direct delivery

Table 6-1 (Dis-)advantages regarding time and costs for transport modes

The tariffs for road transport in China are state-directed prices. An indication for transport of 20 feet containers was 6 yuan/TEU/km and for 40 feet containers this was 9 yuan/TEU/km in 1998[2]. From the table below can be seen that also the port destination is influencing the tariffs for road transport. The much higher transport prices to Hong Kong are not purely based on the longer travel distance (transport to the port of Hong Kong is much more expensive than transport to Yantian).

From	To Yantian Port (US$)		To Shekou Port (US$)		To Hong Kong Port (US$)	
	TEU	FEU	TEU	FEU	TEU	FEU
Shenzhen	79	91	79	91	319	346
Huangpu	193	224	193	218	638	666
Guangzhou	236	266	216	254	665	692
Foshan	302	326	260	296	692	718

Source [42]

Table 6-2 Handling Tariffs for Road Transport in the Pearl River Delta, 1999

2 [29]

In China the tariff for Railway transport, charged on a TEU per kilometre basis was 1.4 yuan/km/TEU for more than 500 km, 1.2 yuan/km/TEU for 1000 km and 1.15 yuan/km/TEU for 1500 km in 1998. The average distance over which rail freight traffic moves in China is 785 kilometres and transport by rail over a distance of less than about 300 km are unlikely.

When containers are transported by inland waterways or, in the case of transport from Yangshan, by sea-river vessel, the additional intermediate unloading and loading charges at the terminals can be avoided. Viewed from the actual expenses of the shipper, the transport tariff of waterways is distinctly lower than that of highway and railway. The standard tariff form Yangtze domestic feeder service between Wuhan and Shanghai for example is 1677 yuan/TEU when a vessel of about 100 TEU is used[3]. With the distance between Shanghai and Wuhan being 1125 kilometres the average price per kilometre is 1.49 yuan/TEU. This price per TEU per kilometre is almost equal to the price of rail transport but when the capacity of the used vessel is increased the price can diminish further because of the economy of scale. This can clearly be seen from the table below. These figures are valid for transport to and from Hong Kong and are for that reason higher than the expected prices of Yangshan.

Vessel size	Vessel Operating Cost (US cent/ton-km)		
(DWT)	Low	Base	High
50	10.78	13.54	16.25
100	7.91	9.31	10.43
300	4.35	5.12	5.74
500	2.38	2.8	3.14
1000	1.23	1.46	1.62
3000	1.0	1.17	1.31

Source: World Bank, 1998 [38]

Table 6-3 Reduction of unit transportation Cost by using larger Size vessels

When the DWT is increased with a factor 60, the vessel operating costs per ton-km are reduced with almost factor 12.

Although the above tariffs for the various modalities are aged, the ratio between them is not likely to change except by capacity increases of the vessels. As the carrying capacity is increasing, the price per TEU per kilometre will diminish and the price for transport over water will become more attractive. The price for water transport might be halved when using larger vessels. This makes the gap between road transport and water transport even larger.

With the vessel sizes increasing, waterway transport is becoming more attractive than rail transport also on large distances. Road transport is a factor 6 to 8 more expensive.

6.2. Infrastructural Development of the Hinterland

Beside the already existing transportation network in China, as described in Chapter 4, also other aspect are of importance for the future use of the infrastructure. The plans that are currently in progress for the development of the infrastructure might be supportive to the infrastructure used by the transportation options from Chapter 5. When an option is using road transport as main hinterland transport a new expressway is of great importance. But beside the plans in progress also the political support for certain transport modes is an interesting aspect in China. When an option is using a logistic centre that is (financially) supported by the Chinese authorities it has a favourable position above options not using this centre.

6.2.1. Plans in Progress

The *national road construction programme* for China focuses on improvement of the rural road network and the expansion and upgrading of the national trunk highway system. Some of the new national trunk highways that are planned to be constructed in the near future are the following[4].

- The Beijing-Shanghai expressway of 1,300 kilometres
- The Shanghai-Chengdu expressway of 2,500 kilometres
- The Chongqing-Beihai expressway of 1,270 kilometres

Especially the Shanghai-Chengdu expressway can improve the accessibility and the economic position of some inland river ports like for example Wuhan.

The *national programme for the rail construction* contains:

- A high speed line Beijing-Shanghai
- Electrification on the routes Chengdu-Kunming and Changdu- Yangpingguan

Excluding the high speed line, new line construction projects fall into three broad categories[4]:

a) new lines in high-density corridors for passenger transport
b) new lines intended to enlarge capacity in corridors which have a vital role supporting economic development
c) new lines intended to provide future international connections.

[4] [38]

One of the main objectives of the national construction programme is relief of the capacity shortages in the densely trafficked network in the eastern part of the country.

For the *inland waterway network* the general emphasis in plans for the construction and development of the inland waterway network is being placed on inland port development and the construction of inland river channels. Port development will include the construction or upgrading of a total of ports along the Yangtze and other rivers. To support the development of Shanghai Port and Yangshan Port the Chinese government initiated two inland shipping projects: the construction of Dalu Waterway and Zhaojiagou Waterway.

Dalu Waterway is 50.5 kilometres long, starts in the Huangpu River and ends at an inland river in the under-construction being Luchao Harbour City. This waterway should be the connection between the Yangtze River network and Yangshan Port. Vessels with a maximum of 1,000 ton will have access to the Dalu Waterway, which is expected to be completed in 2005. The Zhaojiagou Waterway is an already existing waterway that forms the shortest connection between the Huangpu River and the Waigaoqiao terminals. The authorities initiated a dredging programme at a total expected cost of US$105 million. It is expected to be finished in 2005[5].

As the railway network of the hinterland of Shanghai and Yangshan is densely trafficked, options using this modality might experience difficulties. With the new expressway Shanghai-Chengdu especially the position of the port of Wuhan is strengthened. With the two new waterways the accessibility of Shanghai port for inland waterway transport is improved for vessels coming from Luchao Harbour.

6.2.2. Political influences

Since 1978, there has been a gradual trend of responsibilities for infrastructure being shifted to the non-government sectors (privatisation). During the period 1985-1995, central and provincial governments became less and less involved in the direct investment of transport projects but more and more involved in the formulation of supportive and regulatory transport policies and long term transport plans[6]. However, the decision making bodies in China are too diverse and complex. The decision on developments of the railway system are controlled by the ministry of Railways, which has invested most of its attention and capital in the construction of a new express rail system in the country as described in the previous section. This is done to be able to compete with airlines in the domestic passenger market for long-distance travel. The

[5] [45]

[6] [39]

highway network however is under control of the provinces[7]. The same issue can be seen for controlling of the waterways. Of the long inland waterways only the main course of the Yangtze River was controlled by the Ministry of communications. Other waterways and the rest of the Yangtze River was controlled on a local level. The ability of thinking inter-modally is clearly not common in China[8] as organising and controlling the infrastructure on several levels does not stimulate inter-modal transport.

To support the development of Shanghai's logistics industry, the Chinese government initiated a programme for the development of six logistic centres in Shanghai, during the period of the 10th five-year plan (2001-2005). Within these logistics centres, two logistics centres will be constructed nearby the Shanghai port areas. One is Waigaoqiao Logistics Centre. Another is the Luchaogang logistics Centre near Luchao Harbour City, where the supply of the logistics services for Yangshan Port are arranged. The provincial authorities near these ports are pushing the middle-sized ports to gain some share in the booming export business.[9]

6.3. Reliability of the Transport Options

The reliability of road transport is of a lower level than the reliability of waterway and rail transport. Reason therefore is the reliability of the used infrastructures. With the possibility of meeting congestions the reliability of road transport is reduced. Where vessels and trains are functioning according to a fixed plan, for trucks this is hard to realise. Not only the infrastructure is determining the reliability for the eight transportation options in chapter 5. Also the presence of the bridge might be of great influence.

When transportation options are using the bridge between Yangshan and Luchao Harbour City, also the reliability of the use of the bridge should be taken into account. As a chemical terminal is situated south of Yangshan chemical transport will take place underneath the bridge. To determine the reliability of the bridge the consequences of unavailability of the bridge need to be assessed.

With the total number of containers transported over the bridge per year derived from the Chinese Water Design Institute (CWDI) in combination with the operational days of the port, the total number of containers to be transported over the bridge per day can be determined.

[7] [42]

[8] [41]

[9] [18]

When the usage of the bridge is not possible as consequence of an accident, the transport of containers over the bridge cannot take place. In that situation there are two options. The first option is to transport the containers to other ports in the surrounding area like Shanghai and Ningbo by using extra vessels. To realise this, a lot of extra crane movements are needed as the transshipment incident is suddenly increased enormously. Also extra vessels are needed for these transports. Option two is to store the containers at Yangshan Port. To determine the average available slots for this emergency situation first estimation should be made of the number of slots at the port in the normal situation. Therefore the following equation is used:

$$\text{Number of slots} = \frac{\text{throughput per year (TEU)} * \text{dwell time} * \text{peak factor}}{\text{Operational days} * \text{stacking height}}$$

Yangshan Port is operational 365 days a week and the average dwell time is estimated at 10 days[10]. For the peak factor 1.2 is chosen. The normal stacking height on which the dimensions of the port are based is expected to be 4. With the given equation the number of slots can be determined for the design situation.

With the assumption that not all slots are occupied at the moment when the bridge becomes unusable (as a result of an accident), the number of slots that can be used as buffer can be determined. By dividing this number of available slots through the transported containers per day from Yangshan to the hinterland the number of days can be determined that Yangshan can supply a buffer. In the table below the number of containers transported daily over the bridge are presented. As this number is the number of containers in both directions between Yangshan and Nanjing, only half of the number represents transports from Yangshan to Nanjing. When the bridge is unavailable for transport this number needs storage at Yangshan.

Year	Transported over the bridge mTEU per year	Containers over the bridge TEU per day	Container at Yangshan TEU per day
2005	1.120	3,068	1,534
2010	3.700	10,137	5,068
2015	5.700	15,616	7,808
2020	7.900	21,644	10,822

Table 6-1 Number of containers to be stored at Yangshan with an unavailable bridge

When the percentage of occupied slots in the port area is 60%, the number of days Yangshan port can offer a buffer is more than four days as can be seen from the table below.

[10] [18]

Year	Designed slots	Free slots (40%)	Containers per day	Buffer days
	No.	No.	TEU	No.
2005	18,082	7,233	1,534	4.72
2010	55,068	22,027	5,069	4.35
2015	84,658	33,863	7,808	4.34
2020	117,534	47,014	10,822	4.34

Table 6-2 Possible buffer days with an initial slot occupation of 60%

Of course in an emergency situation the stacking height will be increased. When the stacking height is increased to 6 containers the number of buffer days in 2005 increases to 10.6 and in the other years 9.76.

When the percentage of occupied slots in the port area is 80% and the free slots are only 20% of the total, the number of days Yangshan port can offer a buffer is a little more than two days as can be seen from the table below.

Year	Required slots	Free slots (20%)	Containers per day	Buffer days
	No.	No.	TEU	No.
2005	18,082	3,616	1,534	2.36
2010	55,068	11,014	5,069	2.17
2015	84,658	16,932	7,808	2.17
2020	117,534	23,507	10,822	2.17

Table 6-3 Possible buffer days with an initial slot occupation of 80%

When the stack height is increased to 6 in 2005 a buffer can be offered of 8.25 days and in the other years 7.8

When the bridge is unavailable for container transport the maximum number of buffer-days offered by Yangshan is varying from 2 with a slot occupation rate of 80% and a stacking height of 4 to more than 10 days with an initial occupation rate of the slots of 60% and a stacking height of 6.

Even as long as the port can offer buffer storage capacity for the delivered containers still the functioning of the port is heavily disturbed when the bridge can not be used. The supply of containers from Luchao to Yangshan is completely shut down and vessels calling at the port cannot be loaded, as the needed containers are not available. With the absence of a connection with the mainland the port of Yangshan can hardly function.

With the bridge being unavailable Yangshan Port can offer some buffer days but is not able cannot function as a normal port.

6.4. Economic Potential of the Hinterland

When the production and economic development is moving to the west of China, these more inland regions will most likely experience a GDP growth. This was also the situation in the Pearl River Delta. When the manufacturing sector moved here into the delta the GDP growth rate began to increase[7]. Hong Kong and the Pearl River Delta have formed a 'front store-backyard factory' relationship: the port city is in charge of packaging and selling while the region is responsible for production. With the development of the Yangtze River Delta also Shanghai might be able to obtain such relationship. Therefore the transport connections between the two main ports Shanghai and Yangshan must undergo a high degree of development.

When a good transportation option is realised between Shanghai and Yangshan on one side and the hinterland on the other side, there are two categories of regions that can benefit. The first are the 'enclosed' regions. These regions have no direct access to ocean shipping and for which the transport option provides an opening to trade. The second category is the 'saturated' regions. In these regions the trading activity is so intense that road and rail traffic congestion become a major problem and a good transportation chain is needed. An example of this second category is easily given as it represents the situation of Shanghai. For the 'Go-West' policy it is important to determine where the locations of the first category can be found.

To determine the economic cores in the Yangzte River area the GDP development of the provinces can be used as an indicator. As given in chapter 2 Shanghai Municipality, Jiangsu province and Zhejiang Province have relative high GDP values per capita. The GDP per capita of Anhui Province and Jiangxi Province are almost equal while Hubei exceeds them with a factor 1.5. The first three already have a high economic development followed by Hubei.

For the transportation options however it is important to know the cities with a high economic potential. For these locations it is of major importance to have a good transport connection to the ports. When investigating the situation along the Yangtze River the cities with the most important economic potential are Wuhan, Tongling and Wuhu[11]. In order to verify these most potential cities an investigation has been done to the settlements of car manufacturing industry. Because this being an important industry enjoying great esteem in China, the locations of settlement are a good indicator for the potential of the area.

[11] [29]

Investigating the future locations for car industry, Chongqing and Wuhan and Tongling are mentioned[13]. Suzuki will start a production plant in Chongqing while the government wants to use Wuhan for this purpose. According to the central government five-year plan (2001-2005) China will create two to three international competitive big auto groups to deal with challenges arising from the WTO entry. It is very likely that these production plants will have very good connections with the national infrastructure.

The cities with the highest economic potential currently are Wuhan and Tongling. Beside these cities Nanjing, Anqing and Jiujiang are important economic centres.

6.5. Conclusions of long-term development aspects

When determining the most favorable transport option from Chapter 5, also long term development aspects should be taken into account. The four most important ones are:

1. Transport characteristics of the transportation chains

- The different usage of the transport modes results in different transportation costs and different transport times as truck transport for example is faster but also more expensive.

- The tariffs for road transport are state-directed prices. Transport of a 20 feet container costs around 6 yuan/TEU/km (1998). Road transport prices are influenced by the destination (Hong Kong is much more expensive). Railway transport costs on average 1.3 yuan/TEU/km (1998). Inland waterway transport costs around 1.5 yuan/TEU/km (100 TEU vessel). When the capacity of the vessel is increased the price can decrease further because of economies of scale. Loading/unloading charges at the terminals can sometimes be avoided (for example sea-river vessels).

- With vessel sizes increase, waterway transport is becoming more attractive than rail transport, also on long distances. Road transport is several times more expensive.

12 [38]

13 [45]

2. Infrastructural development of the hinterland

- Development plans that are currently in progress might support a certain transportation option. There are various national road and rail construction programmes. Development of the inland waterway network is focused on inland port development and the construction of inland river channels. Port development will include the construction or upgrading of various ports along the Yangtze and other rivers.

- Political influences should be considered; the decision making bodies in China are still very diverse and complex. Decisions on the railway development for example are controlled by the Ministry of Railway. The highway network is under control of the provinces. The main course of the Yangtze River is controlled by the Ministry of Communications whereas other waterways and the rest of the Yangtze River are controlled on a local level.

- The ability of thinking inter-modally is clearly not common in China as organizing and controlling the infrastructure on several levels does not stimulate doing this.

3. Reliability of the transport options

- The reliability of road transport is lower than of waterway and rail transport as traffic congestions can suddenly arise.

- The reliability of the bridge-connection between Yangshan and Luchao Harbour City and consequences of unavailability need to be assessed. When the bride cannot be used as a consequence of an accident, there are two options. The first is to transport the containers to other ports in the surrounding area like Shanghai and Ningbo by using extra vessels. Extra crane movements and extra vessels would be required. The second option is store the containers at Yangshan Port. Calculations show that the maximum number of buffer-days offered by Yangshan is varying from 2 with a slot occupation rate of 80% and a stacking height of 4 to more than 10 days with a occupation rate of the slots of 60% and a stacking height of 6.

- With the bridge being unavailable, Yangshan Port can offer some buffer days, however it is not able to function as a normal port.

4. Economic potential of the hinterland

- For the ‘Go-West’ policy it is important to determine where ‘enclosed’ regions are located. The choice of transport options could provide an opening to trade here.

- To determine the economic cores in the Yangtze River area, the GDP development of the provinces can be used as an indicator. To determine the most potential cities an investigation of the settlement of car manufacturing industry (enjoying great esteem in China) has been done. The locations of settlement are a good indicator for the potential of the area.

- The cities with the highest economic potential currently are Wuhan and Tongling. Beside these cities, Nanjing, Anqing and Jiuliang are important economic centers.

7. Multi Criteria Analysis

For the selection of the best alternative the method of the weighted sum is applied to a Multi Criteria Analysis (MCA). Therefore the effect scores are standardised and multiplied with corresponding criteria weights. For each alternative the sum of the figures is given, which makes it possible to rank the alternatives. A sensitivity analysis is applied to determine the firmness of the MCA before the conclusions are drawn.

The Multi Criteria Analysis is used to determine the most preferable transportation chain for container transport between the port of Shanghai and the port of Yangshan on one hand and the hinterland on the other hand. The eight possible options are given in chapter 5. Because a lot of quantitative aspects are involved in the selection process, a Multi Criteria Analysis is used for this selection.

7.1. Criteria for Transportation Chains

To determine the relevant criteria, a comparison of already existing Multi Criteria Analyses and decision based aspects in the literature[1] was made. This was combined with the described long-term developments in chapter 6. This analysis resulted in 13 criteria for the decision between transportation chains in China. In this paragraph these criteria will be specified and a diagram of the selection process of the choice between transportation options will be given.

7.1.1. Criteria of the MCA

Below, all derived criteria will be defined and the interpretation for the MCA is given.

1) Transport time

Transport of containers will often be done by a combination of transport modes. Some routes may use more water transportation but less land transportation which takes more time. Besides, the more transfers in the transportation chain, the more time the total transport takes. This criterion is determining the total needed time of the transport compared to the transport time of other options.

[1] [29], [27], [2]

2) Transport costs

Like transport time also transport costs are determined by the chosen route/modalities. Routes using more water transportation have lower costs then routes using land transport. This is among other things caused by the higher capacity of vessels per fixed cost. Furthermore, the reduction of the number of transfers will benefit the transportation costs.

3) Plans in progress

The already existing plans in progress might have a supportive function for the infrastructure and therefore also for some of the potential transportation chains. Plans in progress can be seen as an addition to the infrastructural network. The fact that the Port of Yangshan and Luchao Harbour City are completely new logistic centres in China causes that the infrastructure will be constructed in such a way that the needs of the port are optimally satisfied. The plans to construct an express way from Shanghai to Chengdu can also be a stimulating factor for transport over the Yangtze River. Some ports along the Yangtze will have better hinterland connections by this new expressway.

4) Present Network

In this criterion the rate of correspondence between the used transportation chain and the present network is presented. The more similarity between the transportation chains and the current infrastructure network, the more potential the transportation chain has. In Shanghai area the state of development of the highways is quite high, while the ports along the waterways are less established to high container volumes. Another issue here is the fact that the hinterland connections with Yangshan are not yet capable to handle the high container volumes even though a high priority is given. Also the new canals from Luchao Harbour City to the Yangzte River are not constructed yet.

5) Political encouragement

As stated in the previous chapter, thinking inter-modally is not implemented throughout the entire political system of China. Even though inter modal transport is not really enhanced, the government is encouraging transport over water and rail. Besides stimulating the usage of these modalities the governmental preference is also the use of the new port and its facilities. This is not only stimulating for the functioning of Yangshan but also unburdening the capacity of the port of Shanghai.

6) Flexibility

The flexibility of the supply chain is of great importance for production processes. Transportation chains using mainly road transport are more flexible than transportation chains using the different forms of waterway transport. Transfers can cause delays and can reduce the flexibility. On the other hand terminals can also be used as temporarily buffers in time. This can have a positive effect on the flexibility.

7) Maintenance cost

Maintenance of transportation chains can be a complex and important cost-raising issue. Especially dredging channel sections of the Yangtze River is an expensive aspect because of the high sedimentation volumes. On the other hand, in parts of the river where dredging is not necessary because of sufficient natural depth the maintenance cost are low. Maintenance of highways and railways is a constant factor over time. Options using the bridge will experience an extra maintenance aspect.

8) Delay sensitivity

When the transportation chain is obstructed, delays in the supply chain can occur. Possible delays can be divided in two categories: 1. delays on the terminals as result of problems with the transfer or 2. delays during the actual transport as result of a traffic diversion or congestion. The latter has the most chance when containers are transported by road traffic, especially in Shanghai area. Transport over water is less sensitive to these delays. The more transfers made in the transportation chain, the more chance that delays occur. Quantification of the possible occurring delays is a difficult aspect for which a lot of investigation should be done. In this MCA the delays will be approached in a qualitative way.

The presence of the bridge to Yangshan Port is another important aspect in this criterion. With frequent chemical transports expected underneath the bridge, the consequences of a possible collision might be enormous. The occurring delays when the bridge is not operational are extremely high as can be seen from the previous chapter.

9) Capacities

The criterion ‘Capacities’ comprises the capacities of the used infrastructure and terminals. With the growing throughput the current capacities of the highway in Shanghai area are highly utilised with congestions as consequences. The waterways are not seeing this capacity problem with the channels being wide enough. According to the previous chapter the bridge can deal with its container supply as long as it is fully operational. The fact that the throughput capacity of Shanghai is reaching its limit discourages making a lot of transfers at this port. The use of Yangshan port where the capacity is increasing until 2020 is encouraged.

10) Economic Zones

With the criterion Economic Zones, the development and stimulation of new economic centres is meant. This is a supportive aspect to the ‘Go-West policy’ of the Chinese Authorities. In the MCA the transportation chains using the terminals of Shanghai are lower rated than transportation options using other terminals. Reason for this is the fact that Shanghai has an already very developed economy and the contribution to the total economy of extra trade is limited. The contribution of container transport to the developing economies of transportation chains using terminals in new economic centres like Luchao Harbour City and terminals in the Yangtze area like Wuhu for example is much higher.

11) Labour development

The criterion ‘Labour development’ comprises the effects caused by the possible increase of the wages in the future. The consequences of this increase is not equal for all transport modes. Road transport and terminal operations are often labour intensive and therefore more sensitive for increasing wages. Options using (a lot of) these services might in the future experience disadvantages. The attractiveness of these modes can be reduced by the increasing costs.

12) Environmental aspects

Different modes of transport have different consequences for the environment. Transportation options mainly using road transport are lower rated in the MCA than transportation options using mainly transport over waterways as road transport is more harmful for the environment. When using waterways for transport the capacity of the used vessel is also important. Higher capacities of the vessel reduce the number of trips and are therefore less harmful for the environment.

13) Transport Hazards

Looking at the hazards of container transport a division can be made between hazards for transported containers and hazards for the involved part of the Chinese population. Especially when the number of transfers is increasing the chance on accidents with containers is enlarged. Containers might be damaged in this process.

For safety of people, traffic intensity is often determining. Stimulating road transport will cause extra pressure on the highways and might result in congestion and accidents. Also the presence of the bridge can increase the risk as the consequences of accidents happening here is much higher. Using rail and waterway networks the risk for the population is reduced.

7.1.2. Selection Process

The 13 criteria given in the previous section are the basis for the selection process. In this section the selection process is represented schematically. With this selection process the best option can be selected. From this figure can be seen that criteria are grouped. Five groups of criteria can be derived:

- Transport Characteristics
- Infrastructural Aspects
- Reliability
- Economic Potential
- Environment

By introducing these groups of criteria a weight-factor can be specified as to the importance of a criterion. Not only a weight factor will be defined for the group, also for all separate criteria. The final result is therefore more specific.

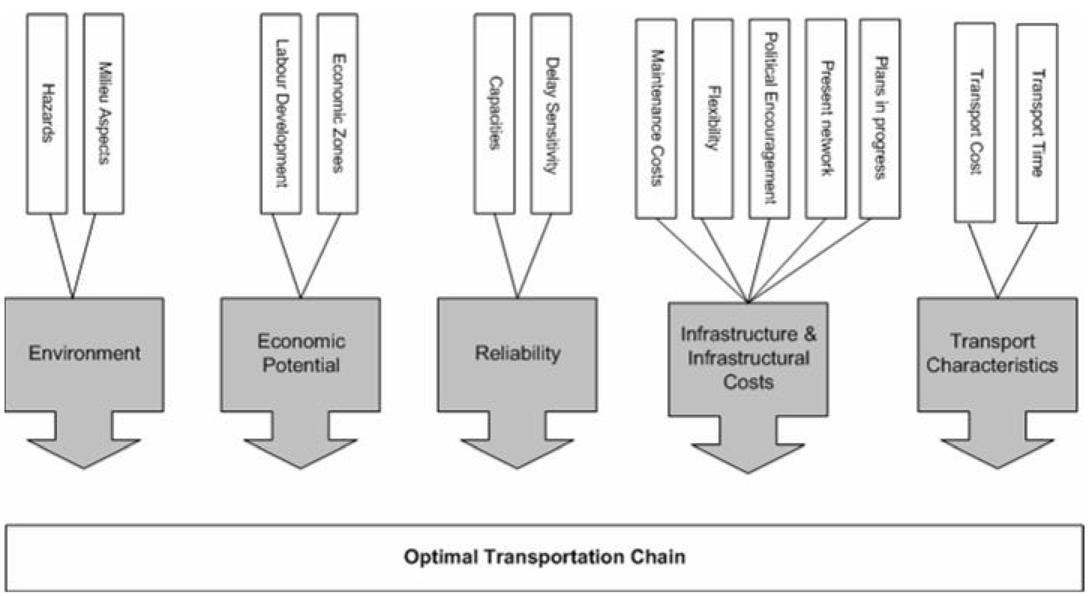


Figure 7-1 Selection Process for Transportation Options between ports and hinterland

7.2. Approach of the Multi Criteria Analysis

After defining the criteria for the selection process, a matrix of standardised effects can be generated. This matrix is called the matrix of effectivity. The unit in which the effects are measured can be qualitative or quantitative. In order to be able to compare and add up the effects of the different criteria, the effects need to be standardised. The strength of this matrix is found in the comparability of the scores on different criteria per alternative. For standardisation two main rules are obeyed:

- Choose the most obvious standardisation method per criterion, and make sure that for each criterion the highest score is given to the most favourable option.
- Make sure that for each row the same interpretation is valid.

In this MCA the following figures are used:

1 = not very good
3 = a little better
5 = much better
7 = clearly much better
9 = absolutely much better
The intervening figures can be used to refine the scores.

Next step is to obtain the weight factors per criterion of the MCA. The weights are a translation of a vision on the selection process and represent the mutual relative importance of the criteria. The interpretation of the weight factors used in this MCA is:

1 = not very important
2 = a little more important
3 = much more important
4 = clearly much more important
5 = absolutely much more important

The decision matrix is found when the matrix of effectivity is multiplied by the weights of the criteria. Adding up the scores per alternative provides the total score per alternative. The alternative with the highest score settles best with all criteria and is therefore the most preferred option to transport containers from port to hinterland and vice versa.

7.3. Weight Defining

In the Multi Criteria Analysis the groups of criteria will receive weight factors, this way the mutual importance to the decision problem can be presented. The criteria that belong to the different groups will also receive weight factors in order to determine the weight division in a group. In the figure below this process is represented followed by the weight defining for all groups and criteria.

For the determination of the weights the vision on the selection process must be defined as it forms the basis for the weight defining. With the quick development of the Chinese economy the number of (rising) difficulties and changing aspects in the future is large. As good transport facilities are to a high degree necessary to keep the economy running and developing further, the weights are defined in such a way that it will support the developing economy as good as possible.

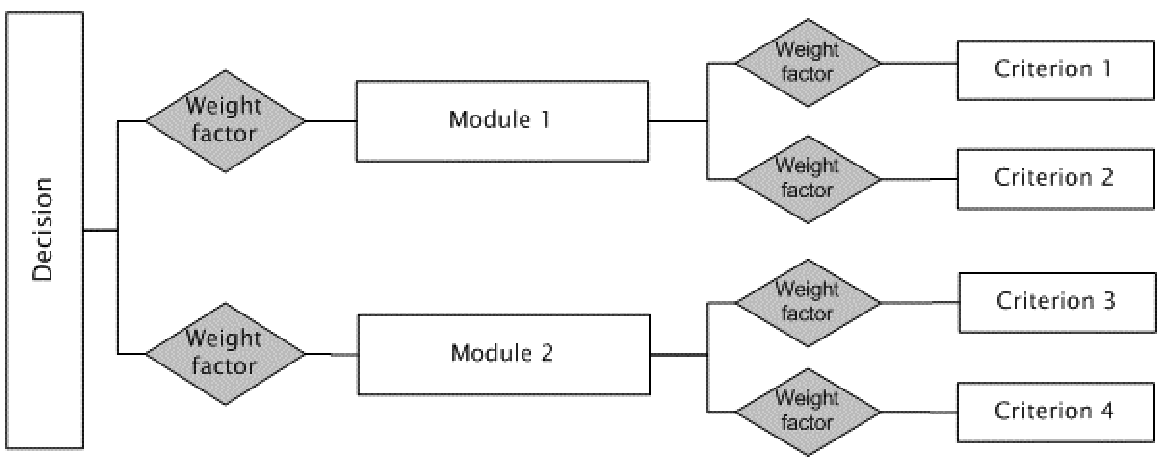


Figure 7-2 Functioning of the MCA

- I. The first group of criteria is 'Transport Characteristics'. This group is most important of all groups because the influence to the choice of a transportation option is very strong. It represents the criteria 'transport time' and 'transport costs'. From the literature can be derived that transport time is the major aspect for the determination of transportation chain to be used, closely followed by the transport costs. Because of this the criterion 'transport time' receives a weight factor 5 while 'transport cost' receives a weight factor 4. When the group 'Transport Characteristics' is compared to other groups of criteria it can be seen that this group is the most important one and therefore rated a factor 5.

- II. The second group of criteria in the selection process is ‘Infrastructural Aspects’. In this group the interests of the Chinese Government, the shippers as well as the interests of the receivers are presented by six criteria. The most important criterion is the flexibility, weight factor 5. This is most important because flexibility is often highly demanded by the receivers of cargo. This is followed by the criterion ‘present network’ and ‘political encouragement’. These two aspects are quite determining for the functioning of the transportation network. These criteria receive 4 as weight factors. The ‘plans in progress’ can be supportive for the transportation chain and receives a weight factor of 3. The last criteria in this group are ‘maintenance costs’, which can turn out to be significantly cost-raising and has a weight factor of 2. The weight factor of this group of criteria is lower than the weight factor of the first group and also less important than the third group of criteria so the weight factor will be 3.

- III. As mentioned above the group of criteria ‘Reliability’ is counting more heavily in the MCA then ‘Infrastructural Aspects’ but less heavily than the ‘Transport Characteristics’. Therefore a weight factor is 4 ascribed. This group contains two criteria. The ‘delay sensitivity’ is the first and receives a weight factor of 5 for the reason that delay is a very hot topic in the transport business as production processes often rely on it. The second criterion ‘capacities’ is also of great importance but a little less than the previous criterion. Therefore ‘capacities’ receives a weight factor of 4.

- IV. The group ‘Economical potential’ consists of the criteria ‘economic zones’ and ‘labour development’. The economic potential can have a steering function in the choice of a transportation chain but is not as dominant as the three previous groups. A weight factor of 2 is the result. Within this group the weight factors for criterion ‘economic zones’ is 4 while the weight factor of the ‘labour development’ is 3. Economic zones over time will have increasing cargo volumes to be transported and such volumes are a main driver in the transport process.

- V. Final group of criteria is the ‘Environment’. In China the environmental consequences are holding a less prominent place in the decision making process than currently in Europe. The group contains two criteria environmental aspects’ with a weight factor of 2 and ‘hazards’ with a weight factor of 3. Hazards are receiving a three as the consequences can be large. The total group receives a weight factor of 1.

7.4. Decision Matrix

The decision matrix can be obtained from the matrix of effectivity and the weight factors of the groups and the criteria. The figures of the criteria per option are multiplied by the weight factors of the criterion and then added up by the other results of the multiplications. This group score is subsequently multiplied by the weight factor of the group. In the figure below an example is given.

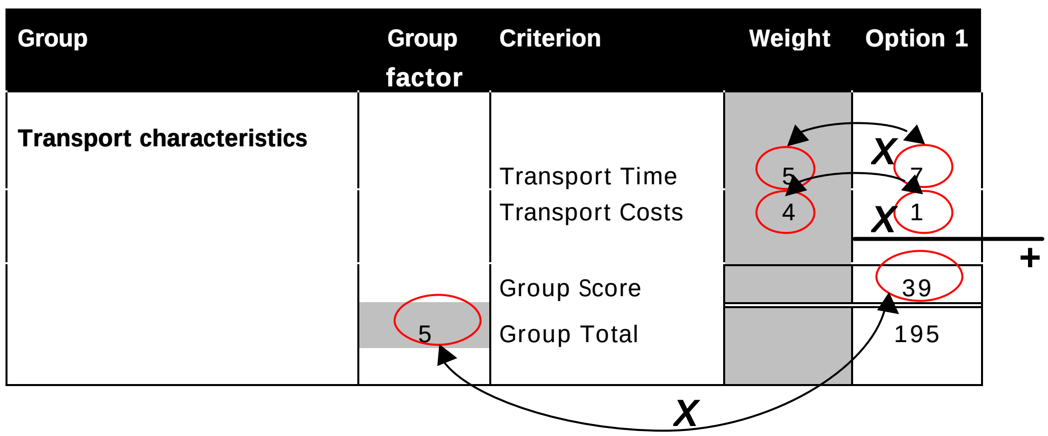


Figure 7-3 Example of the MCA

It can be seen that the weight factor of the criteria are multiplied by the scores per option. In the example this is 5*7 and 4*1. Together this gives a group score of 39. Because the group factor is 5 for 'Transport Characteristics' the final group score is 5*39=195. In the same way the group total can be calculated for all groups. When the group totals of all five groups are added up the final score for option 1 is found.

With the given weight factors the maximum and minimum scores of the MCA can be determined. To obtain these minimum and maximum scores the lowest possible score of 1 should be given to all criteria. When this is done the result is a total score of 154. The maximum score of the MCA is 1386, which is received when all criteria score a 9. When this is also done for the scores of 3,5 and 7 a division of scores can be made. This offers a reference for the result of the MCA. The reference scores are given below.

Reference scores for the MCA

154 - 462	low score	770 – 1078	good score
462 – 770	average score	1078 – 1386	very good score

Group	Group factor	Criterion	Weight	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
Transport characteristics											
		Transport Time	5	7	8	3	5	3	6	5	8
		Transport Costs	4	1	3	5	9	5	1	9	3
		Group Score		39	52	35	61	35	34	61	52
	5	Group Total		195	260	175	305	175	170	305	260
Infrastructure & Infrastructural Costs			Weight	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
		Plans in progress	3	9	9	7	7	5	3	5	3
		Present Network	4	5	5	4	6	6	7	6	7
		Political Encouragement	4	5	5	7	6	3	2	4	3
		Flexibility	5	9	7	4	6	4	7	6	7
		Maintenance Costs	2	6	7	5	4	4	5	4	7
		Group Score		124	116	95	107	79	90	93	98
	3	Group Total		372	348	285	321	237	270	279	294
Reliability			Weight	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
		Delay sensitivity	5	2	4	5	9	7	3	9	4
		Capacities	4	5	4	7	9	6	3	7	4
		Group Score		30	36	53	81	59	27	73	36
	4	Group Total		120	144	212	324	236	108	292	144

Economic Potential			Weight	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
		Economic Zones	4	4	3	7	7	5	3	5	3
		Labour Development	3	3	4	5	7	5	3	7	4
		Group Score		25	24	43	49	35	21	41	24
	2	Group Total		50	48	86	98	70	42	82	48
Environment			Weight	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
		Milieu aspects	2	2	3	6	8	6	2	7	3
		Hazards	3	3	5	6	7	6	4	7	5
		Group Score		13	21	30	37	30	16	35	21
	1	Group Total		13	21	30	37	30	16	35	21
Total Score				750	821	788	1085	748	606	993	767

From the MCA the ranking of the options can be found

Ranking of the options

1: Option 4
2: Option 7
3: Option 2
4: Option 3
5: Option 8
6: Option 1
7: Option 5
8: Option6

7.5. Sensitivity Analysis

The purpose of a sensitivity analysis is to verify the firmness of the result of the MCA. As explained before the definition of criteria is the translation from a vision on the transportation chains to weight factors. The given MCA so far is based on the maximum support for the development of the economy by the transportation options. But also other visions are possible.

7.5.1. Optimal service for the customer in the MCA

With the rapid development of the economy transport is becoming more and more important. The customer, using the transport modes and the infrastructure, is getting more and more demanding as good transport is getting more determining for the competitive position of a company. An example is coming up of the Just-In–Time services. When the weight factors in the MCA are made representative for the optimal services for customer the result of the MCA will change.

For the customer the ‘transport time’ is important and especially the control of the transport time must be developed to a high degree. The weight factor will therefore become 5. The ‘transport cost’ will be charged to the customer the lowest possible transport costs will be welcomed. The weight factor given to this criterion is also 5. For customers using the transportation options the ‘plans in progress’ are of medium importance. When the plans become operational they can benefit from but they are not depending on it. The weight factor will be 3. The ‘present network’ is of much more importance. With this network they have to realise their transports. A weight factor of 5 is given. The ‘political encouragement’ and the ‘maintenance cost’ are aspects less relevant for the customers. Therefore these two criteria will be rated low: the applied weight factors will be 2 and 1 respectively. ‘Flexibility’ on the other hand is of major importance. Flexibility in the supply of imported containers and exported containers also gives the possibility to have a flexible production process. The weight factor will be 5.

‘Sensitivity for delays’ and ‘capacities’ are also important for the production processes. When delay of transport becomes the bottleneck for the production process the production cost can strongly increase. A weight factor of 5 is given to this criterion. The capacities of the infrastructure obtain weight factor 4. The connection of the infrastructure with the economic zones with a high development potential obtain a weight factor 5 as these locations can be potential areas to settle for a lot of customers. The development of labour is relevant for the customers as this could make vessels more attractive (increasing labour prices). In order to switch a modality, a lot of changes might be necessary in the planning of the supplies. A weight factor 4 will be given. The environmental aspects are not very important for the customer, a weight factor of 1 is given. Hazards on the other hand can also have influence on the containers and receive for that reason a weight factor 2.

The result of applying the weight factors as described above to the MCA are given in the table below.

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
Total Score	731	806	780	1113	769	611	1030	770

From this table can be seen that option 4 is the option with the highest score and therefore the most preferred option for the customer followed by option 7. This is equal to the initial MCA. Compared to the result of the initial MCA only option 5 climbed in the ranking to position 6, exceeding option 1 and option 6.

The options preferred by the 'optimal service' customers are option 4 and option 7. These are the same options as in the initial MCA.

7.5.2. Optimal Environmental Protection in the MCA

Even though environmental aspects have not the role they currently have in Europe it might come up in the future. With a population of 1.3 billion a lot of improvements can be made. When one has a high priority on harming the environment to the minimum the weight factors will change.

As waterway transport causes the least burden for the environment, the 'transport time' clearly becomes less important (transport time by vessels is also relatively long). This criterion therefore obtains a weight factor 2. The weight of the 'transport cost' will increase for the same reason. The result is a weight factor of 5. When the transport options are fitting very well with the 'plans that are already in progress' the need for other new constructions, which could harm the environment, is diminishing and therefore the weight of this criteria will increase. This criterion therefore obtains a weight factor 4. The same can be said for the 'present network'. This is even more important than the 'plans in progress' and obtains a weight factor 5. As the Chinese government is currently not giving a high priority to the environmental aspects the matching with the 'political encouragement' is rated low: weight factor 1. 'Flexibility' means more transports and lower occupation rates of the capacity of the used transport mode. For the protection of the environment the flexibility will be rated low, weight factor 2, just like the 'maintenance costs' with a weight factor 2.

As delay sensitivity for road transport is high and congestions give an extra burden on the environmental aspects the ‘delay sensitivity’ is preferred to be kept low. A high weight factor of 5 is the result. Also for ‘capacities’ a high weight factor is wanted as extra pressure on already overloaded terminals and infrastructure is asking for extension of the facilities: weight factor 4. For the prevention of the environment the connections between the developing ‘economic zones’ and the transport modes are preferred to be very efficient. A high rate is given therefore to this criterion: 4. As the development of wages is stimulating waterway transport (which is most environmental friendly) the weight factor for this criterion is high, but lower than the one of ‘economic zones’. It will be given a weight factor 3. Environmental aspects will logically obtain the highest possible score: 5. as Hazard happening might burden the environment a weight factor of 3 is given.

With the above described weight factors the result of the MCA will change. The final result is given in the table below.

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
Total Score	572	659	720	1010	716	476	927	611

From this Table can be seen that option 4 is ranked in the first position followed by option 7. This is equal to the ranking of the initial given MCA. The third position in this situation is for option 3 and compared to the initial MCA this option climbed one position in the ranking. Option two has the fifth position.

When the weight factors for maximum support of the environmental aspects are applied to the MCA transport option 4 is the most preferred option followed by option 7. This top two is the same as in the initial MCA.

7.5.3. Other verifications

Beside the determination of the sensitivity to other visions on the selection process in the MCA also the sensitivity for changes in the extremities in the weight-factors and the scores are determined. In the first three verifications therefore changes are made in the various weight factors. By changing the weights of the criteria and the weight of the groups, the influence of these weights on the outcome of the MCA becomes clear. When the weights are changed, also the minimum and maximum score of the MCA is changed and therefore the reference scores. For that reason the new reference score division is given when the weights are changed. In the last two verifications some of the extremities in the figures per criterion are changed. In this way the sensitivity to the figures can be determined.

In order to keep the results of the sensitivity analysis conveniently arranged, only the final result of the MCA will be given.

Verification 1

In the MCA two groups have received very high weight factors: 4 and 5. In order to determine the influence of these high rankings the weight factors of the groups Transport Characteristics, Infrastructure and Infrastructural Costs and Reliability are in this verification all equally rated with a group weight factor of 3. The final result of the MCA in this situation is:

Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
642	681	665	882	619	511	798	627

The score division with these weight factors is as following.

127 - 381	low score
381 – 635	average score
635 – 889	good score
889 – 1143	very good score

With a score of 882 Option 4 is doing best, followed by option 7 with a score of 798. The ranking by score of all the options gives for the first four positions the same ranking as followed from the MCA. Changing the high group weight factors into average weight factors does not have consequences for the choice between transportation options.

Verification 2

The influence of the fact that two groups, Economic Potential and Environment, are rated relatively low is established by changing the weight factors of these groups to 5. The final result of the MCA is in this situation:

Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
877	977	1037	1380	973	733	1256	923

195 - 585	low score
585 – 975	average score
975 – 1365	good score
1365 – 1755	very good score

When the options are ranked, it can be seen that option 3 and 2 exchanged places: Option 3 takes over the third position of Option 2. The ranking of the two first options remains the same even though the group weight factors of Economic Potential and Environment are changed.

Verification 3

From the MCA and the verifications above can be seen that Option 4 is scoring very high. In this verification the weights of the criteria on which option 4 scores very high (9) are reduced by one, so the weight of the criterion Transport Cost becomes 3, of Delay sensitivity becomes 4 and the weight of the criterion Capacities becomes also 3.

Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
717	774	715	968	671	577	884	720

138 - 414	low score
414 – 690	average score
690 – 966	good score
966 – 1242	very good score

The result of this verification is the same ranking as the ranking from the MCA for the first three positions. Option 4 is still in first position, followed by option 7 and option 2.

Verification 4

The sensitivity of the outcome of the MCA is also determined by the consequences of changing the figures of the options per criterion. To examine these consequences first all figures 9 of option 4 are changed into 8 and second they are reduced by 2 and changed into 7. The result for the MCA is as following.

Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
750	821	788	1029	748	606	993	767

Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
750	821	788	973	748	606	993	767

When all the scores of nine are changed into 8, the ranking is still the same as the ranking received from the MCA, even though the score of option 4 is lower. When the figures are again reduced by one and the figures 9 are changed into 7, the ranking changes: Option 7 takes over the first position and option 4 becomes second.

Verification 5

From the MCA and the above mentioned changes becomes clear that option 7 and option 2 are the options closest to the score of option 4. For that reason it is interesting to investigate the situation when all figures of option 2 and 7 are increased by 1. An exception is made for the figures 9, they stay the same, because 9 is the maximum on the used scale. The result of this change in the MCA is given below

Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
750	966	788	1085	748	606	1107	767

Option 7 is exceeding the score of option 4, and option 2 is getting closer to the very high scores of option 7 and 4 when this change is applied to the MCA.

According to this investigation of the sensitivity of the Multi Criteria Analysis, changes in the weight factors of the groups and the criteria are not changing the final ranking. The stability of the result of the MCA when the figures per criterion are changed is less solid. In that case option 7 and option 2 are getting closer or are even exceeding the score of option 4.

7.6. Result of the Multi Criteria Analysis

Based on the result of the Multi Criteria Analysis and the sensitivity analysis option 4 and option 7 are receiving the highest scores. In the table below can be seen that for the ranking of the optimal service to the customer as well as for the ranking of the environment both option 4 and option 7 are equal to the result of the initial MCA. Where option 2 for the initial MCA and for the 'customer-MCA' is ranked on third position, for the 'environment-MCA' this is option 3.

	Ranking MCA	Ranking for Customer	Ranking for Environment
Option 1	6	7	7
Option 2	3	3	5
Option 3	4	4	3
Option 4	1	1	1
Option 5	7	6	4
Option 6	8	8	8
Option 7	2	2	2
Option 8	5	5	6

Table 7-1 Comparison of ranking of the Results from the visions on the MCA

It can also be seen that in all MCA's option 6 is the option with the lowest score. Beside the changes in visions also changes in the extremities were made. The comparison of these results is given in the table below.

	Ranking MCA	Verification 1	Verification 2	Verification 3	Verification 4(1)	Verification 4 (2)	Verification 5
Option 1	6	5	7	6	6	6	6
Option 2	3	3	4	3	3	3	3
Option 3	4	4	3	5	4	4	4
Option 4	1	1	1	1	1	2	2
Option 5	7	7	5	7	7	7	7
Option 6	8	8	8	8	8	8	8
Option 7	2	2	2	2	2	1	1
Option 8	5	6	6	4	5	5	5

Table 7-2 Comparison of ranking of the Results from the verifications with the MCA

These scores demonstrate that the best way to transport containers is via the Yangzte River. Transport directly from Yangshan (option 4) is preferred above transport from Shanghai (option 7). The difference between these two options is mainly caused by the different scores for plans in progress, present network, political encouragement and capacities. Also the environmental issues show better results with option 4. The fact that these options are the best scoring is confirmed and even strengthened by the sensitivity analysis. Attention should be paid to the fact that transporting containers from Yangshan by road transport without paying a visit to Luchao Harbour City is a very strong competitive transportation chain.

From the sensitivity analysis also becomes clear that the figures per criterion for each option are of great importance to the mutual position of option 4 and 7. Actually the scores are close to each other compared to the scores of other options. For this reason it seems likely to further investigate to which extend large scale transport over the Yangtze River from the Port of Shanghai as well as from the Port of Yangshan is actually achievable.

With transport of containers from the main ports to the hinterland the use of the Yangtze River is preferred above other transport options.

Even though from this MCA seems to become clear that transport over the Yangtze river from both ports is the best transportation option, further investigation is needed before one can state that these forms of transport are achievable. The navigability of the Yangzte River for the actual container flows over the river has to be determined. Beside these aspects of capacity also the impact of the costs should be further investigated.

7.7. Conclusions regarding the MCA

- To determine the most preferable transportation chain between the port of Shanghai and the port of Yangshan on one hand and the hinterland on the other hand, the method of the weighted sum is applied to a Multi Criteria Analysis (MCA).

- The MCA uses 5 main criteria groups under which a total of 13 individual criteria are placed. The groups and criteria have been selected as follows:

1. Transport characteristics (weight-factor 5), which includes: Transport time and Transport Cost,
2. Infrastructural aspects (weight-factor 3), which includes: Plans in progress, Present network, Political encouragement, Flexibility and Maintenance costs,
3. Reliability (weight-factor 4), which includes: Capacities and Delay sensitivity,

4. Economic potential (weight-factor 2), which includes: Economic zones and Labour development and
5. Environment (weight-factor 1), which includes: Environmental aspects and Transport hazards.

- As good transport facilities are to a high degree necessary to keep the Chinese economy running and developing further, the weights to the above 5 main criteria groups are defined in such a way that it will support the developing economy as good as possible.

- Sensitivity analysis have been done to see the outcome of the MCA when the vision/goal of the transport chain is changed into 'Optimal service to the customer' and thereafter into 'Optimal environmental protection'. Also, sensitivity for changes in the extremities in the weight-factors and the scores were determined.

- The scores demonstrate that the best way to transport containers is via the Yangtze River. Transport directly from Yangshan (option 4) is preferred above transport from Shanghai (option 7). The difference between these two options is mainly caused by the different scores for plans in progress, present network, political encouragement and capacities. Also the environmental issues show better results with option 4. The fact that these options are the best scoring is confirmed and even strengthened by the sensitivity analysis.

- Attention should be paid to the fact that transporting containers from Yangshan by road without paying a visit to Luchao is a very strong competitive transportation chain.

- Although from this MCA it becomes clear that transport over the Yangtze River is the best transportation option, further research is needed. Amongst others, the navigability of the Yangtze River with the actual container flows should be investigated.

8. Usage of the Yangtze River for Container Transport

8.1. Characteristics of the Yangtze River

With a length of 6300 kilometres the Yangtze River is the longest river of China and the third of the world when it comes to length. It originates in the Geladandong Mountains and crosses 12 provinces before it flows into the East China Sea.

Figure 8-1 Course of the Yangtze River

The whole Yangtze can be divided into three reaches: the upper reach, the middle reach and the lower reach (see Table 8-1). The upper reach of the Yangtze River includes several mountainous rivers with high slope riverbeds and many shoals. Along this strech the river passes through the Three Gorges in Hubei Province near Chongqing. The middle reach of the Yangtze River flows through most of Hubei Province and Hunan and Jiangxi provinces. The middle reach is considered to be the most heavy flood risk area of the whole Yangtze River. The drop distance over the length of 955 kilometres is between 40 and 50 metres.

Yangtze River	Upper reaches	Middle reaches	Lower reaches
Range	river source to Yichang	Yichang to Hukou	Hukou to river mouth
Length (km)	4.505	955	840
Mean Width (m)	10-100; 300-800	800-1000	>1000
Watershed area (km^2)	1.0 million	0.68 million	0.12million
Drop distance (m)	5.100	40-50	<20
Large Cities	Chengdu, Chongqing	Wuhan	Nanjing, Shanghai

Table 8-1 Characteristics of the lower, middle and upper reach of the Yangtze River

The lower reaches of the Yangtze River run from Hukou (at the mouth of Poyong Lake, the largest lake in China) to the East China Sea. The Yangtze River is here broad and deep. Downstream of Datong, see Figure 8-2, the tidal influence can be noticed. The landscape in the river's lower course is typified by a flat delta plain, criss-crossed by canals and waterways. The drop distance is less than 20 metres.

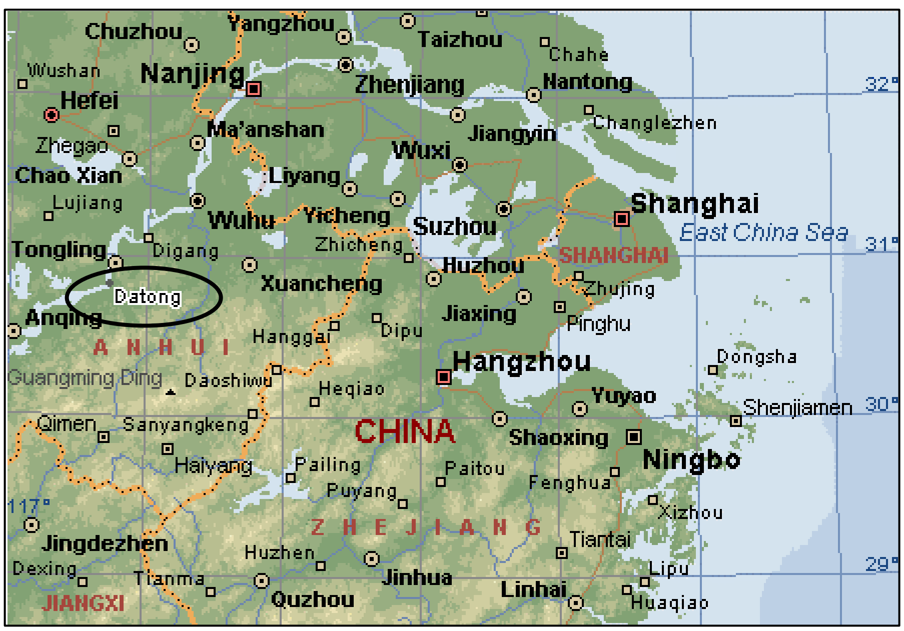


Figure 8-2 Tidal reach up to Datong at the Yangtze River

The main characteristics of the Yangtze River are given Table 8-2.

Yangtze Characteristics			
Length Yangtze River	6,300	km	
Area Yangtze River Valley	18,085	million km^2	19% of China
Discharge of river estuary (mean)	32,400	m^3/s	Rhine is 2,200 m^3/s
Annual mean total discharge volume	951.3	billion m^3	
Annual precipitation (mean)	1,070.50	mm	

Source Masterplan Study Report [29]

Table 8-2 Main Characteristics of the Yangtze River

The wet season in this area starts in April, bringing heavy rains in the middle and lower reaches. Floods in the Yangtze may occur especially between May and October but are concentrated in July and August. Normally, the lower reaches experience flooding earlier than the middle and upper reaches[1].

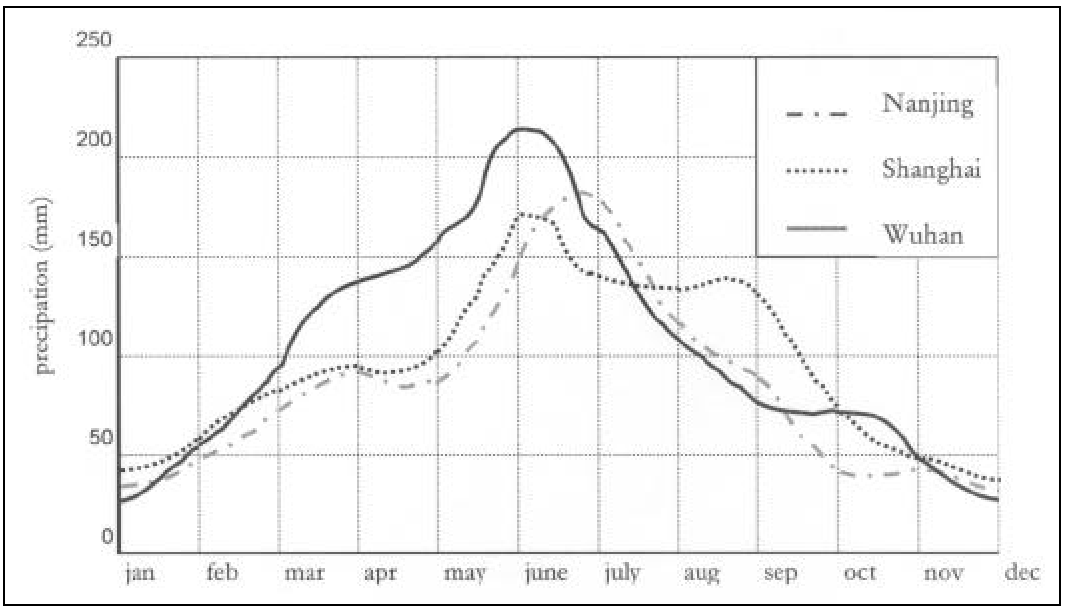


Figure 8-3 Precipation at Nanjing, Shanghia and Wuhan in mm [32]

Due to the rains the water level of the river knows level differences. Some locations like Wuhu even see differences of 17 metres. Floating cranes solve the problems caused by these differences at the terminals.

1 [32]

8.2. Navigability of the Yangtze River

For the navigability the depth of a river is the main parameter. This can also be seen in paragraph 3.3.1, Depth restriction of the Entrance Channel. Discharge of the river and tidal influences determine the changes in the water level along the Yangtze River. Beside the actual depth also the guarantee of a certain depth is of great importance for the navigability. Only a depth with a high guarantee is useful to draw conclusions on the navigability. The depths of the Yangzte River and the guaranteed rate of these depths are given in percentages in Table 8-3.

River Section	Length (km)	Size of navigation channel (m)		Guaranteed rate of waterdepth (%)	Maximum tonnage of navigable vessels (ton)
		Depth	Width		
Channel at the river mouth	45	9.0	-	95	25,000
Wusongkou-Nanjing	435	10.5	200	95	25,000
Nanjing-Anqing	305	4.5	100	98	5,000
Anqing-Wuhan	400	4.0	100	98	5,000

Table 8-3 Navigation Characteristics of the Yangtze River between Shanghai and Wuhan, [29]

According to the table above the Yangtze River between Shanghai and Wuhan can be divided into four sections. The first two sections, from the river mouth to Nanjing, can be navigated by vessels of 25,000 ton. The depth of the river mouth is maintained at 8.5 metres by dredging according to chapter 3. At Wusongkou the river is deepening to 10.5 metres. Upstream from Nanjing the depth is reduced to 4.5 metres and here the river is navigable only for vessels of 5,000 ton. At Anqing the river depth is further reduced to 4.0 metres.

The navigability of the river is also influenced by hydraulic structures. The total Chinese waterway network contains 900 navigational structures such as ship-locks and ship lifts. Among these is the enormous lock in the Three Gorges Dam near Jiujiang. This lock has become operational half 2003. The total water level distance this five-steps-lock has to bridge is in first instance 75 metres and will finally be in 2009 more than 100 metres.
Another important structure is the Yangtze River Bridge upstream from Nanjing. Because of this bridge and the reduced water depth upstream of Nanjing only vessels with maximum 5,000 tons are able to pass the bridge.

The Chinese fleet navigating the inland waterways numbers 231,000 with a total deadweight tonnage of 20.67 million and a passenger seating capacity of 780,000[2]. Among this fleet a lot of passenger vessels are found that are converted to container

[2] [18]

vessels. The mean TEU capacity of the Chinese fleet is low. This causes problems with the usage of inland waterways for large scale container transport. This is subscribed by a quote of the managing director of P&O Nedlloyd Logistics China, Peter Lee:

> *"P&O Nedlloyd would like to make much more use of the Chinese waterways. We use them as much as possible. The problem with the Chinese inland shipping is the fact that a large number of companies conduct a huge fleet of small vessels. These small vessels, from 10 to 108 TEU can not offer the needed economy of scale"* [3]

Currently larger vessels navigating the Yangtze River are the ones used for direct short-sea transport to ports in the first section of the river like Nantong, Zhangjiagang and Nanjing. Even though the small container vessels are dominant in number also some larger vessels of for example 400 TEU are found quite regularly[4].

8.3. Container-flow over the Yangtze River

To investigate the role of the Yangtze River in the transport of containers the container flow is calculated from Yangshan and Shanghai. These calculations are based on the modal split expectations of Shanghai Port and Yangshan Port, from chapter 4.

Yangtze river transport of Yangshan Port

The prognoses of container volumes transported from Yangshan Port over the Yangtze River can be extracted from the modal split figures for Yangshan in chapter 4. In the table below the share of containers transported over the Yangtze River to the total throughput of Yangshan Port is given.

Year Yangshan	Yangtze Transport (mTEU)	% of Total Port Throughput
2005	0,100	4.55
2007	0,300	7.50
2010	0,650	9.70
2015	1,100	10.68
2020	1,700	11.89

Table 8-4 Container transport over the Yangtze River from Yangshan Port

[3] [48]

[4] [22]

The container volume transported over the Yangtze is strongly increasing from 2005 to 2020. While in 2005 only 4.5% of the throughput is transported over the Yangzte in 2020 this almost 12%

Yangtze River Transport from Shanghai Port

In the modal split of Shanghai Port the percentage of containers over the Yangtze is not specified separately in section 4.1.1. All sorts of water transport are combined and represented together in the modal split of Shanghai. Even though the Yangzte River is the largest river by far, containers may also be transported over water via the Grand Canal or other smaller rivers. Therefore it is assumed that 80% of the water transported containers use the Yangtze River as their main waterway. With this assumption the total container volume transported over the Yangtze River from and to Shanghai Port can be determined. In Table 8-4 this container volume is given in combination with the share this volume is of the total expected throughput of Shanghai port.

Year Shanghai	Yangtze Transport (mTEU)	% of Total Port Throughput
2005	1,966	19.85
2007	1,775	17.75
2010	1,584	15.68
2015	1,455	13.60
2020	1,296	11.89

Table 8-5 Container transport over the Yangtze River from Shanghai Port

In this table is beside the total container volume transported over the Yangzte also the percentage given this volume is of the total throughput of Shanghai. From 2005 to 2020 the proportion of the river transported containers is diminishing from almost 20% to almost 12%. Not only the percentages are diminishing also the actual volume in mTEU transported over the Yangtze from Shanghai Port will lower over time. Other modalities will take over as is know from chapter 4. From the modal split of Shanghai prognoses for 2015 and 2020 are not available. To be able to determine the development of container transport at the Yangzte River also after 2010 the figures of Shanghai are compared with the Yangshan figures. The diminishing trend is continued and is finally set on the same value as Yangshan in 2020.

Combination of both ports

When the container volumes of both ports are added up the container flow from Shanghai and Yangshan over the Yangzte is obtained, see Table 8-6. It can be seen that it takes until 2015 before the contribution of both ports to the Yangtze transport have become almost equal.

Year	Total Yangtze Transport (mTEU)	Shanghai (%)	Yangshan (%)
2005	2,066	95.2	4.8
2007	2,075	85.5	14.5
2010	2,234	70.9	29.1
2015	2,555	56.9	43.1
2020	2,996	43.3	56.7

Table 8-6 Container flow and proportions of Shanghai and Yangshan

During the period 2005-2020 the increase of the total container volume over the Yangtze is 45%.

Even though the throughput of Yangshan is booming the role of Shanghai in the transport over the Yangtze River should not be underestimated because before 2015 the share of Shanghai Port is dominant over share of Yangshan Port.

To determine the actual container flows to and from the ports along the river the ratio between import and export is needed. These are obtained from the Chinese Water Design Institute (CWDI). The import is expected to be 48% while the export is expected to be 52%. These figures are valid for all coming years, according to the CWDI. With these figures the container flow from both ports to the Yangtze River for 2005 is represented in Figure 8-4.

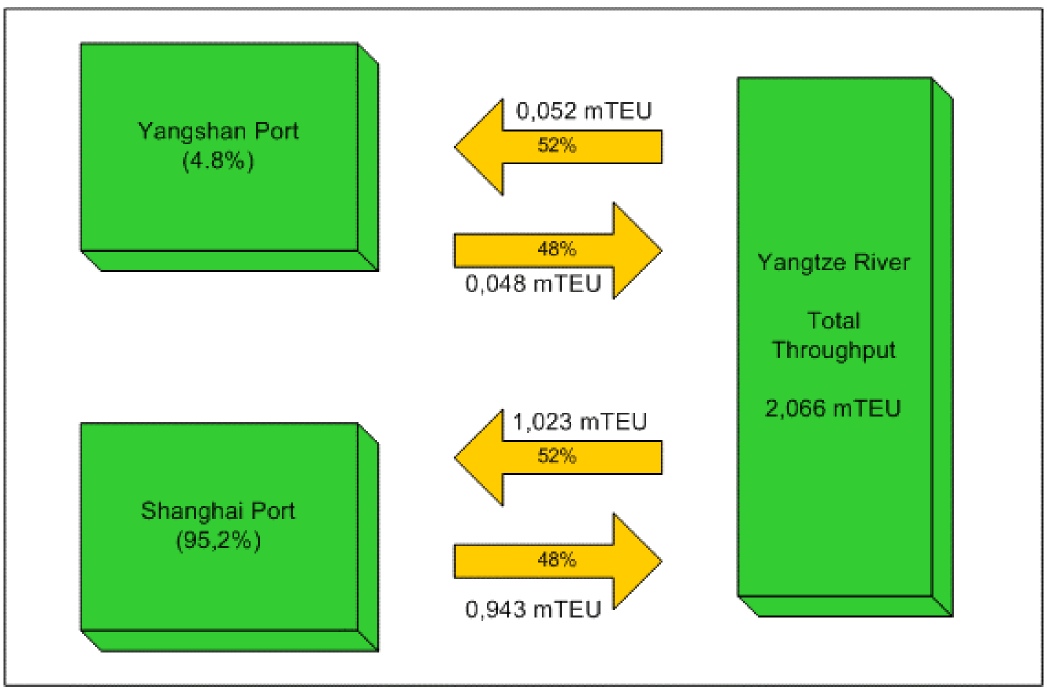


Figure 8-4 Expected Containerflow to the Yangtze River for 2005

Beside the container transport from Yangshan and Shanghai to ports along the Yangzte also direct short-sea transport is occurring to three ports in the first river section: Nantong, Zhangjiagang and Nanjing. In 2000 these ports together accounted for 263,000 TEU short sea transported. In 2010 more than 540,000 TEU is expected to be transported via short-sea services to these ports[5]. This volume will be included in the investigation into the container volumes transported over the Yangtze River.

8.4. Central ports along the Yangzte River

Along the Yangtze River ports of several sizes and scales are found. Downstream of Wuhan 16 major ports are found of which six are the most important in the region. More detailed information about the 16 ports can be found in appendix 11. Most of the containers transported from or to Shanghai over the Yangtze River have currently their destination or origin at one of the six major ports. These six ports are marked as central ports in the Yangtze River area in the Masterplan[6] after the investigations of the Sino-Dutch joint research team. The six central ports are, going upstream from the river mouth:

- Nantong
- Zhangjiagang
- Nanjing
- Wuhu
- Jiujiang
- Wuhan

These ports have large contributions to the handling of containers over the Yangtze and have, compared to other ports along the river, high throughputs. In Table 8-7 the expected contribution to the total container flow over the Yangtze River is given for all six ports, according to the Masterplan. With only the figures for the years 2000 and 2010 being available, the trend of development should be approached carefully. However, the increasing or decreasing trend over the 10 years of the prognoses is given at the right side of the table.

[5] [29]

[6] [29]

Port	2000 (%)	2010 (%)
Nantong	18.6	13.1
Zhangjiagang	19.7	14.8
Nanjing	27.3	32.3
Wuhu	8.1	10.4
Jiujiang	2.0	0.7
Wuhan	8.1	10.9
Other Ports	16.2	17.8
Total	100	100

Table 8-7 Share of ports to the total throughput over the Yangtze

From this figure can be seen that Wuhan, followed by Wuhu and Nanjing, have an increasing contribution to the total throughput transported over the Yangtze. The contribution of the ports closest to Shanghai, Nantong and Zhangjiagang are expected to see their share in river trade throughputs decrease. However, the actual throughput is expected to increase. The container volume of transported containers over water of Jiujiang is constant, with as a consequence the contribution to the total throughput will be reduced.

The importance of the six central ports along the Yangtze is subscribed by the fact that these ports together account for nearly 84% in 2000 and over 82% in 2010 of total river throughput, as can be derived from Table 8-7.

8.5. Port of transshipment

Going upstream, the total volume of containers transported over the Yangtze River with origin or destination the central ports is decreasing. Because calling at many ports has proven to be uneconomical it is interesting to investigate the development of a transshipment port along the Yangtze River. Containers with destinations or origins more upstream of the transshipment port will be transshipped from large vessels to smaller ones. The latter will transport the containers to and from the more upstream ports. When the figures from Table 8-7 are placed in a flow chart, see Figure 8-5, it can be seen that the container flow in percentages is strongly reduced when passing Nanjing. The figures are the expected values for 2005.

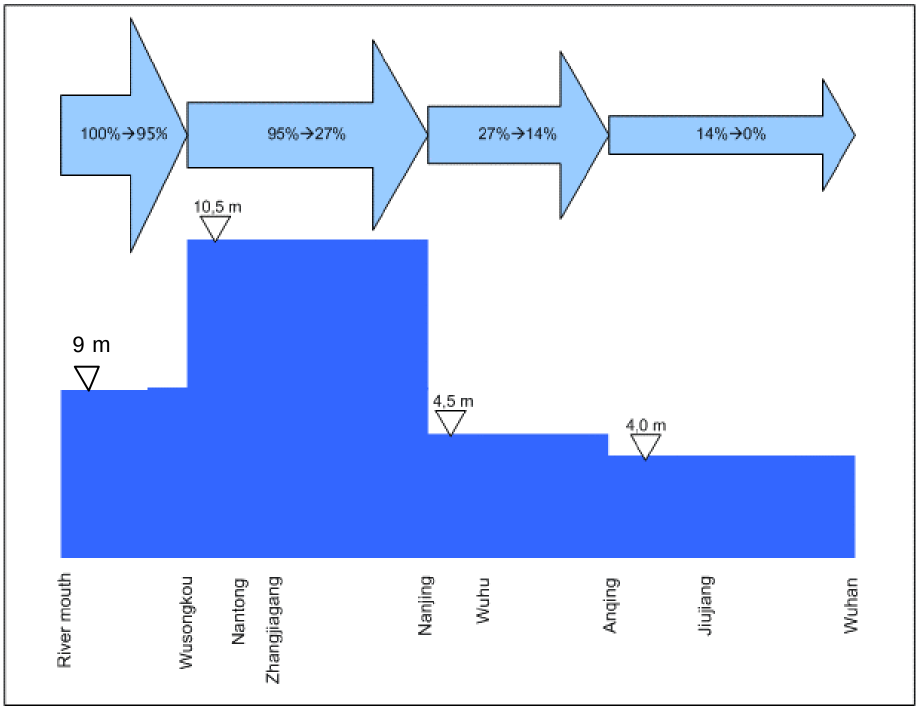


Figure 8-5 Container flow percentages for the main ports along the Yangtze River, 2005

About 25% of the containers transported over the Yangtze have destinations upstream of Nanjing while about 30% is destined for Nanjing Port. When all containers for Nanjing and further upstream are direct transported to Nanjing the transport costs can be reduced because of economy of scale. Because of these figures and the fact that navigation possibilities are limited upstream of Nanjing, the development of a logistic centre at Nanjing with a transshipment port is attractive. This is subscribed by the relatively low state of development of the ports more ports upstream. A shortage of dedicated container spreaders and terminal handling equipment is found. Containers with destinations further than Nanjing and coming from Shanghai and Yangshan could be transhipped at Nanjing.

Figure 8-6 Location of Nanjing at the Yangtze River

Nanjing is also a good location for an inland transfer centre as the prices in Shanghai are continuously increasing. Consequently companies are looking for locations to settle more to the west. Developing Nanjing as a transshipment port is a step for the "Go-West Policy", see chapter 2.

Development of Nanjing as transshipment port will cause an increase of the throughput of Nanjing. To determine this increase and the consequences for the facilities of the port an investigation will be made in the following chapter.

8.6. Conclusions of the usage of the Yangtze River

- With the uncertainties of the varying discharge and tidal influences the navigability of the Yangtze River is determined by its guaranteed depth profile.

- According to its depth profile the Yangtze River can be divided into four sections. The section at the river mouth has a guaranteed depth of 8.5 m maintained by dredging. The second section going upstream has a guaranteed depth of 10.5m. These two sections can be navigated by vessels of 25,000 ton. Upstream of Nanjing, the third and fourth section with guaranteed depths of respectively 4.5m and 4m can be navigated by vessels of 5,000 ton.

- The average TEU capacity of most vessels of the Chinese fleet navigating the Yangtze River is low. Offering a good economy of scale for inland navigation at large scale is difficult.

- To investigate the role of the Yangtze River the volume of container transport from Yangshan Port and Shanghai Port to the hinterland over the Yangtze River is determined. These calculations are based on the modal split expectancies for both ports.

- The share of the total throughput transported between Yangshan and the hinterland over the Yangtze river is increasing from 0.100 mTEU and 4.55% of the port's throughput in 2005 to 1.700 mTEU and 11.89% of the throughput in 2020 while the share of containers transported between Shanghai and the hinterland via the Yangtze River is decreasing from 1.966 mTEU and 19.85% of the port's throughput to 1.296 mTEU and 11.89% in 2020. It is not until 2015 that both ports transport almost equal volumes over the Yangtze River. During the period 2005-2020 the increase of the total container volume over the Yangtze is 45%.

- Most of the containers transported over the Yangtze River have destinations or origin in one of the six central ports along the Yangtze. These ports are Nantong, Zhangjiagang, Nanjing, Wuhu, Jiujiang and Wuhan. Together these ports account for over 80% of the river throughput.

- Nanjing will become the linking port of the Yangtze River middle and lower reaches. With 25% of the containers passing Nanjing and 30% destined for Nanjing while the river depth is there reduced to 4.5m Nanjing offers a good location for a transshipment port. This port of transshipment will know different functions. It can become the transshipment port for deep-sea containers from Shanghai and Yangshan. Secondly Nanjing will become the transshipment port of domestic services for ports upstream of Nanjing.

9. Development of the Port of Nanjing

With the relatively well-developed economy and trade of Nanjing and the favourable natural navigation channels, the port of Nanjing has a strong position. Being an open water port Nanjing has the advantage to be always accessible as no locks need to be passed. For the entrance of the port the full width of the entrance channel can therefore be used. With the varying water levels caused by increased discharge of the river and the sedimentation, the port could however experience disadvantages from being an open water port.

Vessels calling at Nanjing navigate on the Yangtze River's main channel which is over 10 metres deep. Upstream from Nanjing the Yangtze River Bridge is found. Because of this bridge and the reduced river depth the river section upstream from Nanjing is navigable for 5000-tonners while the section below accommodates 25,000 ton vessels all the year round (see chapter 8). The port is situated within the tidal reach and at Nanjing the tidal range is about 0.7 metres[1].

9.1. Current capacity of Nanjing Port

Nanjing Port has two dedicated container terminals at present. One berth is located at the stevedoring district number 4 and the other is located at stevedoring district number 5, see Figure 9-1. The container berths have a length of respectively 186 metres and 224 metres and are both 11 metres deep[2]. With this length and four gantry cranes, two per berth, the total capacity of these berths is together 140,000 TEU[3] per annum.

A new terminal is located on the Yangtze River downstream from the already existing terminals and is 910 m long and has become operational at the end of 2002. The terminal is equipped with three 25,000 ton berths and two 1,000 ton berths. The terminal is designed to have a capacity of 520,000 TEU per annum.

[1] [16]

[2] [3]

[3] [29]

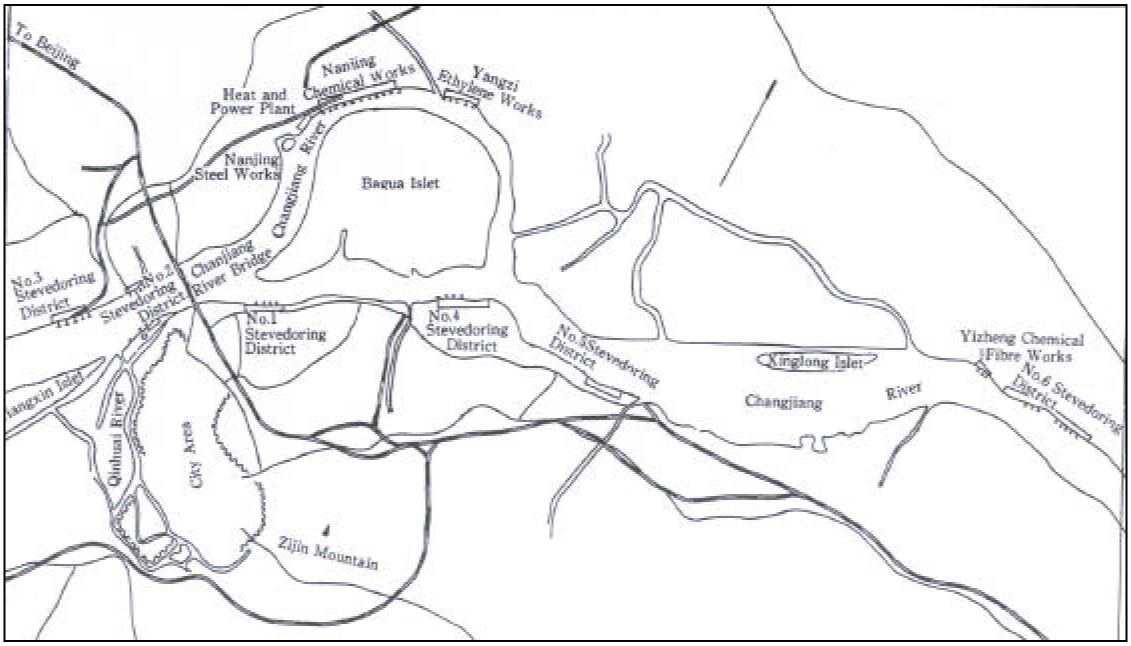


Figure 9-1 Terminals at the Port of Nanjing

Up until 2010 the addition of 800,000 TEU of extra capacity is planned[6] by adding 6 extra domestic container berths and 1 extra sea-vessel berth. The latter will be converted from a general cargo terminal to a dedicated container terminal. Assuming the capacity of the last 800,000 TEU becomes operational phase by phase; 400,000 in 2007 and 400,000 TEU in 2010, the development of the total planned capacity can be represented as given in Figure 9-2. The expected length of the berths is so far unknown.

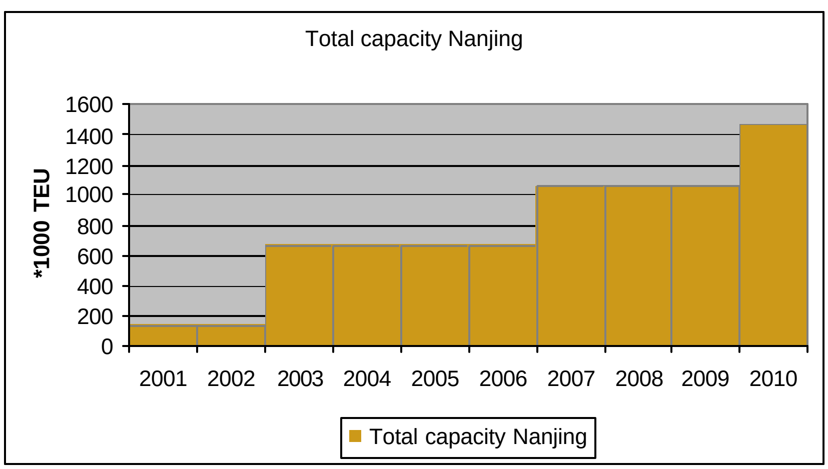


Figure 9-2 Development of the total capacity of Nanjing Port 2001-2010

[4] [3]

[5] [29]

[6] [29]

From this figure and the information above can be resumed that:

- Until 2003 the total design capacity is 140,000 TEU with a total berth length of 410 m.
- Until 2007 the total design capacity is 660,000 TEU with a total berth length of 1320 m.
- Until 2009 the total design capacity is 1,060,000 TEU with a total berth length of more than 1320 m. Addition of berth length unknown.
- In 2010 the total design capacity is 1,460,000 TEU with a total berth length of more than 1320 m. Addition of berth length unknown.

9.2. Expected Total Throughput of Nanjing

To determine the future throughput of the port the container volume to Nanjing is needed. Because Nanjing should become the transshipment port for containers with a more upstream destination or origin also this container volume is needed. In this section the future throughput of Nanjing will be determined based on the container volumes transported over the Yangtze River as calculated in the previous chapter.

27.3% of all Yangtze container transport was transferred at Nanjing in 2000 and 18.2% of the containers was transported to or from Wuhan, Jiujiang or Wuhu. In 2010, 32.3% of the container volume is expected to be transported over the Yangtze to Nanjing and 22% to the upstream central ports. The actual calculation of the container volumes and flows is given in appendix 12.

Four kinds of calls are made at Nanjing. These four are:

- Sea-river transport calls from Yangshan Port
- River transport calls from Shanghai Port
- Short-sea calls
- Domestic calls from ports upstream of Nanjing

The throughput generated by all four kinds of calls and the total throughput is given in the table below.

Year	Shanghai TEU	Yangshan TEU	Short Sea TEU	Domestic TEU	Total TEU
2005	981,450	49,490	170,500	415,266	1,616,700
2007	924,320	156,760	193,500	435,750	1,710,325
2010	860,060	353,000	228,000	491,480	1,932,542
2015	824,300	624,380	285,500	587,650	2,321,835
2020	765,390	1,002,250	343,000	719,040	2,829,680

Table 9-1 Expected total throughput of Nanjing 2005-2020

From the table above can be seen that the expected total throughput for Nanjing in 2005 is 1.617 mTEU and for 2020 2.830 mTEU. The throughput of Nanjing is mainly generated by the container volume between this port and the ports of Shanghai and Yangshan and the short-sea services. Also the container volume with more upstream port destinations adds throughput. To obtain the total throughput also the transshipment at Nanjing is included.

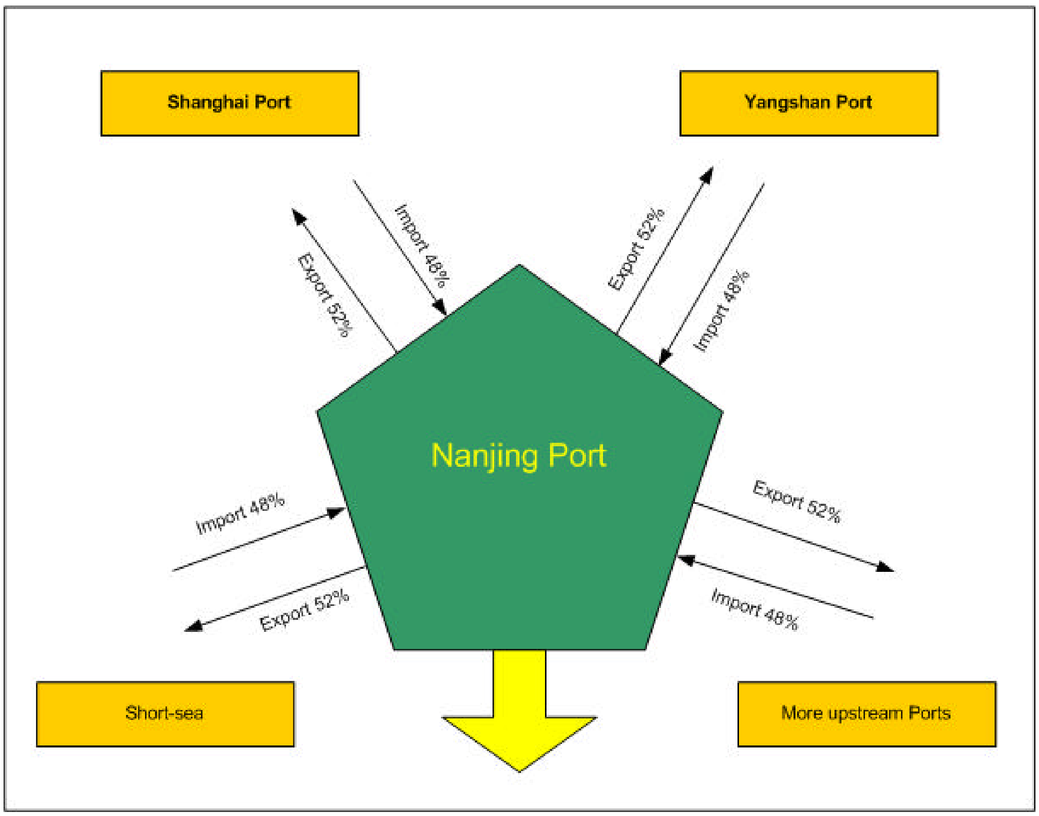


Figure 9-3 Waterborne Container flow at Nanjing

With this large number of containers it is interesting to determine the number of calls when all containers are transported by liner services. Liner trade is the trade of a company which maintains regular services between certain ports. In this case it is interesting to introduce liner services between Nanjing and Shanghai and between Nanjing and Yangshan. Advantage of using liner services is the high reliability. Moreover, when the arrival times are known it is possible to offer a fixed berth location at the port.

With the large number of containers transported to Nanjing from the coastal ports it is interesting to introduce liner services between these ports.

With the information of the previous section can be concluded that the expected throughput is exceeding the current capacity and the planned capacity as is also demonstrated in Figure 9-3. According to Section 3.3.2 the transshipments are the main cause. But also without the transshipment the expected throughput is exceeding the (planned) capacity. The throughput is increase is mainly the consequence of the fact that Nanjing is in the previous chapter chosen as the transshipment port along the Yangtze River.

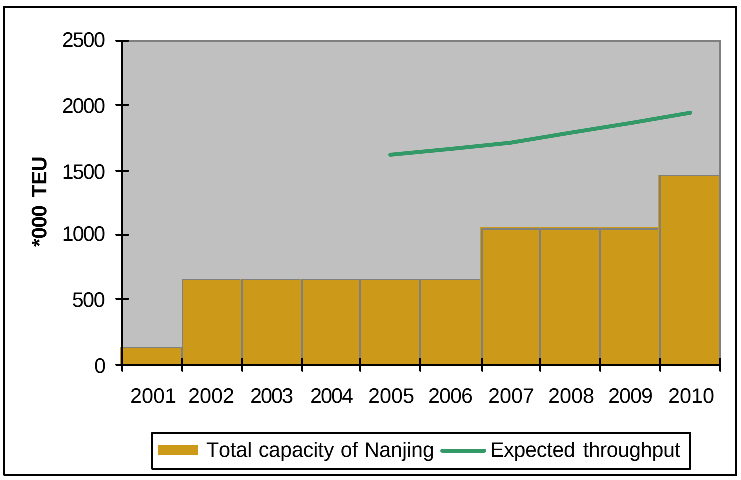


Figure 9-4 Capacity of Nanjing versus the expected Throughput

To solve the problems caused by the differences between capacity and expected throughput extra terminal capacity should be added. But before this can be determined the number of calls and the design vessels have to be calculated.

9.3. Design vessel for Container Transport over the Yangtze River

Depth is the limiting factor for navigation over the Yangtze River. Of the involved river sections, see Section 8.2, the section between Wusongkou and Nanjing is the deepest. The depth profile of the river mouth is influenced by the progress of the Chinese dredging programme. To determine the maximum depth of the vessels the following expression is used[7]:

$$d = D - T + s_{max} + r + m \quad \text{With} \qquad (9\text{-}1)$$

d	=	guaranteed depth
D	=	draught design ship
T	=	Tidal elevation above reference level
s_{max}	=	Maximum sinkage
r	=	vertical motion due to wave response
m	=	remaining safety margin

At the river mouth the tidal influence are of much larger scale then at Nanjing and the influence of T at the river mouth can be determining for the design vessel. At Nanjing the influence of the tide can be noticed but is not very large compared to the river mouth. The mean tidal range at Nanjing is 0.5 metres[8]. Repeating from Chapter 3 the normative water levels at the river mouth are:

- ? MHWS 4.1m above CD
- ? MHWN 3.0 m above CD
- ? MLWN 1.6 m above CD
- ? MLWS 0.5 m above CD

The level of average values is set at 2.3 metres, see appendix 14.

In the figures below the situations for the river mouth and Nanjing respectively are given at MLWS. The situations and vessel depths given in these figures are representative for all days of the year and at all whether conditions because of the use of MLWS as reference level and the UKC. Because of the continuity of the liners first only the all day entrance is determined and is the influence of the tide not included. For the river mouth

[7] [17]

[8] [16]

the dredging phases are of importance for the design vessels as can be seen from the figure.

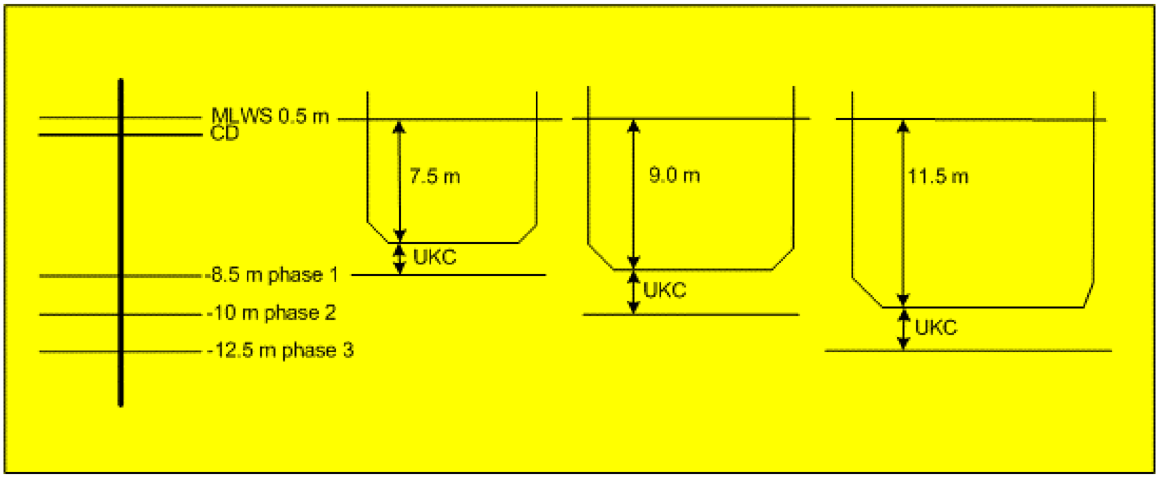


Figure 9-5 Depth profile and accompanying design vessel at the River mouth

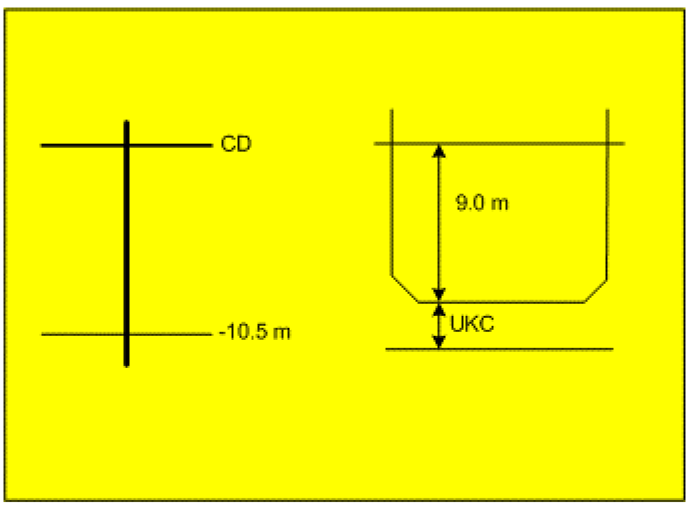


Figure 9-6 Depth profile and accompanying design vessel at Nanjing

Even though vessels with a draught of 11.5 metres can enter the river mouth at low tide when the third dredging phase is realised, they still cannot navigate to Nanjing. The depth of the second river-section is too shallow for these vessels. Therefore only dredging phase two is of importance for the accessibility of Nanjing Port.

To contribute to the accessibility of Nanjing Port the depth required at the river mouth is maximum 10.5 m. Dredging phase three is therefore not needed for transport to Nanjing

For further investigation of the design vessel, assumptions are made for the dimensions of these vessels. This can be found in the appendix 13. Hereunder the dimensions of the normative vessels[10] at the river mouth and at Nanjing are given.

At the river mouth	*Phase 1*	Length	178.5	m
		Draught	7.37	m
		Capacity	700	TEU
	Phase 2	Length	158.1	m
		Draught	8.91	m
		Capacity	969	TEU
From Shanghai to Nanjing		Length	158.1	m
		Draught	8.91	m
		Capacity	969	TEU

The choice of the design vessels for the river mouth can be influenced by the water level rises caused by the tide. In appendix 14 an assumption for the tide expression is made. To bridge the 1.5 metres difference in depth between dredging phase 1 and 2 the water level must rise by tide, obviously, 1.5 m. A minimum of 2.0 m above CD is needed. According to the appendix the tide provides this depth or more about 58% of the time.

9.4. Determination of Calls at Nanjing from all vessels

The total container volume between Nanjing and other ports was calculated in the previous chapter. With these figures the number of calls is determined. As mentioned before the import and export are not equal in China. With 52%, the volume of export containers is determining the number of calls. Empty slots during import trips are the consequence. By the determination of the calls it is assumed that the liner services are 51 weeks per year operational as weather conditions might cause cancellation of trips.

[9] [47]

[10] [47]

9.4.1. Calls from Shanghai Port

Calls from Shanghai will be made by a design vessel with a capacity of 969 TEU. With the container volumes from the modal split Section 9.2 the number of calls can be determined. The actual calculation is given in the appendix 15.

Year	Calls/wk no.	TEU/trip	% of Ship capacity
2005	11	1750	90
2007	10	1813	94
2010	10	1686	87
2015	9	1796	93
2020	9	1668	86

Table 9-2 Number of weekly calls from Shanghai

The number of calls of liner services between Nanjing and Shanghai port will over time diminish from 11 in 2005 to 9 in 2020. With the decreasing container volume also the occupation of slot capacity for the liner vessels will diminish.

9.4.2. Calls from Yangshan

The determination of the calls from Yangshan is a little more complex because the dredging programme is involved. For each year in the prognoses the number of calls is determined for both dredging phases. Per year is decided how many calls are most favourable and also there the influence of the tide is taken into account.

Year	Dredging phase	Design Vessel TEU	Calls/wk no.	TEU/trip	% of slot capacity
2005	phase 1	700	1	970	69
	phase 2	969	1	970	50
2007	phase 1	700	3	1024	73
	phase 2	969	2	1537	79
2010	phase 1	700	6	1154	82
	phase 2	969	4	1730	89
2015	phase 1	700	10	1224	87
	phase 2	969	7	1749	90
2020	phase 1	700	15	1310	94
	phase 2	969	11	1787	92

Table 9-3 Number of calls per dredging phase from Yangshan

Number of calls in 2005

In 2005 the number of calls from Yangshan is very limited. Therefore an investigation of using the tide is not even necessary. With 1 call per week the planning is not difficult at all. Because of the low occupation of the slot capacity a vessel of 700 TEU will be brought into action on this liner service.

Number of calls in 2007

The differences between the occupation of the slot capacities is only 5%. Also the number of calls is close. With phase 1 of the dredging programme 3 calls per week are necessary. To reduce the number of calls in the first phase of the dredging programme to 2 calls per week it is possible to use other vessels with higher capacities. To be able to pass the river mouth the tide can be used.

The minimum capacity of the vessel must in that case be 800 TEU (The export volume per week is 1600 TEU, see appendix 13, so for two calls a vessel of 800 TEU minimum is needed) When the design vessel of 1150 is used with a draught of 8.71 m, see appendix 14, an extra depth of 1.21 m is required (8.71m-7.5m=1.21m). The level of the tide should therefore be 1.71 metres (MLWS is 0.5 above CD and the extra depth of 1.21together). In 66% of the time this is occurring. With two calls per week this should be possible to plan. Therefore in 2007 from Yangshan 2 calls per week will be made at Nanjing.

Number of calls in 2010

In this situation the second dredging phase becomes attractive. Two calls per week can be saved by using a vessel of 969 TEU. Because of the good occupation rate of the slot capacity (a peak can be higher than these average rates) the usage of other vessels is not interesting to investigate. To be able to call at Nanjing with a vessel of 969 and pass the river mouth an extra depth of 1.41m is required (8.91m – 7.5 m= 1.41m). The level of the tide should therefore be 1.91 metres (MLWS is 0.5 above CD and the extra depth of 1.41together). According to the appendix about the tide this is the case in 60% of the time. With 3.5 hours needed to pass the river mouth it is still possible, good planning is demanded. But the cost reduction and the higher occupation rate will probably make it worth. Therefore in 2010 4 calls will be made from Yangshan to Nanjing with a vessel of 969 TEU.

Number of calls in 2015

The differences between the number of calls is increasing with the transported container volume of 2015. Using vessels with a capacity of 700 TEU in total 10 calls per week should be made. When vessels of 969 TEU are used this is reduced to 7 calls, which is daily. Both options have a high occupation of the slot capacity, respectively 87% and 90%. With a availability of 60% of the time it might become difficult to plan the liner service every day. Initiation of dredging phase 2 is preferred.

When the depth of the entrance channel becomes 10 metres the tide can still be used to reduce the number of calls. The design vessel of 1,150 TEU, see appendix 13, has a draught of 9.50 metres. The minimum needed depth for this vessel is 9.5m plus1.5m UKC gives 11 metres. This gives no problem at all with the tide because a water level of 1.0 above CD is even lower than MLW. Only the guarantee is lower than when using the MLWS. Although for the river mouth the vessel of 1,150 TEU seems to be a good option, the river section from Shanghai to Nanjing has a limited depth of 9 metres for a vessel. Therefore the design vessel of 969 TEU is used with 7 calls per week.

Number of Calls in 2020

Compared to 2015 the number of calls per week increased strongly. In 2020 15 calls of 700 TEU are needed with an occupancy rate of 94% to transport all containers to and from Nanjing. Using 969 TEU vessels 11 calls per week are needed.

Resuming the calls made from Yangshan to Nanjing for the period 2005 –2020:

2005	1	call per week
2007	2	calls per week
2010	4	calls per week
2015	7	calls per week
2020	11	calls per week

9.4.3. Calls from Short-sea

Nanjing is already in use as a port for short sea transport. Even though these transports might not be liner, the determination of calls is done in the same way. Because short-sea vessels need to pass the river mouth here also the influence of the dredging should be included. In the table below the results are given.

Year	Dredging phase	Design Vessel TEU	Calls/wk no.	TEU/trip	% of slot capacity
2005	phase 1	700	3	1114	80
	phase 2	969	2	1672	86
2007	phase 1	700	3	1265	90
	phase 2	969	3	1265	65
2010	phase 1	700	4	1118	80
	phase 2	969	3	1490	77
2015	phase 1	700	5	1120	80
	phase 2	969	3	1866	96
2020	phase 1	700	5	1345	96
	phase 2	969	4	1681	87

Table 9-4 Number of calls per dredging phase for short-sea vessels

The expected number of calls is not high compared to the other calls. With this number of calls it might be interesting to use the tide. When for the calls from Yangshan in 2015 the depth is dredged to 10 m. the short sea vessel of course can also profit.

Resuming the calls made by short-sea vessels for the period 2005 –2020:

2005	2	call per week
2007	3	calls per week
2010	3	calls per week
2015	3	calls per week
2020	4	calls per week

9.4.4. Calls from ports more upstream

Upstream of Nanjing the river depth is only 4.5 metres. At Anqing, see section 8.2, it is even further reduced to 4 metres. Tidal influence is not present so the vessels transporting containers to Wuhan, Wuhu and Jiujiang should have limited depths. The maximum vessel depth is 3 m. and because of the berths at Nanjing a maximum tonnage of 1,000 ton is required. This results in vessels of 108 TEU.

From the table the number of calls per week from domestic vessels at Nanjing can be derived for the period 2005-2020.

Year	Calls/wk no.	TEU/trip	% of Ship capacity
2005	40	204	94
2007	42	204	94
2010	47	205	95
2015	56	206	95
2020	68	207	96

Table 9-5 Number of calls from domestic vessels

9.4.5. Total Number of Calls and Vessels at Nanjing

River trade vessels coming from Shanghai and Yangshan and the short-sea vessels all use the same berths at Nanjing. Therefore all calls from these sorts of transport are added up. The domestic vessels, with their much smaller size use domestic berths. The total calls at the river-trade berths and the calls at the domestic berths are given in the table below.

Year	Domestic Calls/wk	River-trade Calls/wk	Total Calls/wk
2005	40	14	54
2007	42	15	57
2010	47	17	62
2015	56	19	75
2020	68	24	92

Table 9-6 Total number of calls at Nanjing Port

During the period 2005 to 2020 the number of calls is increasing strongly, namely almost 60%. This increase will have great impact on the dimensions of the port. In the next section these global dimensions shall be determined.

With the total number of calls being calculated also the number of needed vessels for the liner services to Shanghai port and Yangshan Port can be determined with the needed time for a turn around trip. Before this can be done some requirements are needed:

Requirements

Gross crane production at Shanghai	=	35 moves /hour /crane[11]
Number of cranes per berth at Shanghai	=	2
Gross crane production at Nanjing	=	25 moves per hour per crane
Number of cranes per berth at Nanjing	=	2
Vessel speed	=	12 knots

Required number of vessels between Nanjing Port and Shanghai Port

The navigable distance between Nanjing and Shanghai is 392 kilometres. When the vessel speed is about 12 knots (1.852 kilometres per hour) the total needed time for navigation over the entire distance is 17.64 hours. Extra time for mooring is set a 3 hours in total. When the time needed for maintenance is excluded the turn around time can be determined.

The vessel is loaded and unloaded twice during a turn around: once at Nanjing and once at Shanghai. At Nanjing the moves per hour per berth are 50 while at Shanghai this is 70 moves per hour per berth. For this rough indication the queuing theory is not applied. Therefore the occupancy rate of the berths is high. When a more precise calculation is wanted the queuing theory should be used.

In 2005 11 calls were made with 1750 TEU, see section 9.4.1. Therefore the service time at Shanghai will be 1750/70= 25 hours. At Nanjing the service time will be 1750/50=35 hours. The total needed time for a turn around trip is (2* navigation time) + service time at Shanghai + service time at Nanjing + (2* mooring time):

(2*17.64) + 25 + 35+ (2*3) = 101.3 hours

Per week 11 calls are made, in total 11* 101.3 = 1114 hours of vessel services are needed. With the assumption that a vessel is operational for 24 hours a day and 7 days a week the number of needed vessels is 1114/(7*24) = 6.6. For the

[11] [28]

liner service between Shanghai and Nanjing in 2005 therefore 7 vessels are needed.

In 2007 10 calls are made with 1813 TEU aboard. When the same calculation is made as given above 6.16 or 7 vessels are needed per week. In 2010 10 calls are made with 1686 TEU. With the same approach as for 2005 the liner service needs in 2010 5.90 vessels. Six vessels should consequently be put into action. For 2015 this is 5.51 and also this year six vessels are needed. In 2020 9 calls are made at Nanjing with 1668 TEU per trip. With the above given calculation 5.3 or 6 vessels are needed to realise the liner service between the two ports.

Required number of vessels between Nanjing Port and Shanghai Port

As Yangshan is located further from Nanjing as Shanghai the navigation time will be larger. The navigable distance between Nanjing and Yangshan is 500 kilometres. When no changes are made in the vessel speed the total needed time for one way navigation is 22.5 hours. The gross crane production of Yangshan is assumed to be equal to the one of Shanghai: 70 moves per hour per berth. Also the extra time for mooring is not changed compared to Shanghai.

For 2005 a calculation of the required number of vessels is not necessary as per week 1 call is made. Consequently only one vessel is needed. For the year 2007 2 calls of 1537 TEU are expected. This results in 2 vessels as the value is 1.23. When the calculation is applied on the transports between Yangshan and Nanjing in 2010 with 4 calls of 1730 the needed number of vessels between these two ports is 2.63. Three vessels are needed to realise the liner service. In 2015 7 calls are expected with on average 1749 TEU. This results in a value of 4.62 and therefore 5 vessels. In 2020 in total 8 vessels are needed with 11 calls of 1787 TEU as the calculated value is 7.35.

Total required number of liner vessels

The total number of liner vessels that are required for the services between Nanjing and the two main ports is given in Table 9-7.

	Shanghai- Nanjing no. of vessels	Yangshan- Nanjing no. of vessels
2005	7	1
2007	6	2
2010	6	3
2015	6	4
2020	6	8

Table 9-7 Total required number of liner vessels for 2005 to 2020

From this table can be seen that the number of vessels in the liner services between Shanghai and Yangshan is hardly diminishing. The number of vessels in the liner services with Yangshan however is strongly increasing from 1 vessel in 2005 to 8 vessels in 2020. In 2007 the vessel that is no longer needed for transport between Shanghai and Nanjing might be used for services to Yangshan. However, the dimensions of the vessel determine whether this is possible as the vessel than has to cross a sea-section.

9.5. Conceptual Dimensioning

A global configuration of Nanjing Port is determined in this section. A division in three parts is made. First the conceptual dimensions of the terminal are determined for 2005. This is followed by the determination of the required dimensions for 2010 and by the dimensions for the year 2020. Only for 2005 the complete calculation is given. The calculations of the other years are based on the same equations as given for 2005. In all three parts the berths for smaller domestic vessels and the berths for larger (short-sea) vessels, called River-trade berths, are treated separately. After giving the requirements for the port planning the dimensions will be determined. These will also be compared to the current dimensions of the port and compared with the already existing expansion plans for the container terminals.

9.5.1. Requirements for the planning of the port

The requirements for the port planning are divided into starting points and assumptions as given below.

Starting points

- The dimensions of the port are based on the dimensions of the design vessels
- Only 20 feet and 40 feet containers will be handled
- The calculation of the number of calls base don the container volume calculations over the Yangtze River are the basis for the calculation of the port dimensions.

Requirements

Operational time of Nanjing Port	51	weeks
	357	days
Operational hours a day	24	hour/day
Gross Production of crane at Nanjing	20	moves/hour
Gross Production of crane at Shanghai	35	moves/hour
Gross Production of crane at Yangshan	35	moves/hour

TEU factor	1.5	(-)
Cranes per berth River trade vessels	2	(-)
Cranes per berth domestic vessels	1	(-)
Required area per TEU	13	m^2
Average dwelltime for Nanjing	7	days
Stacking height at Nanjing	3	(-)
Occupancy rate at Nanjing	0.65	(-)

9.5.2. Dimensions of the port for 2005

The calculation of conceptual dimensions consists of the determination of the number of berths for river-trade vessels, which are the liner vessels to Shanghai and Yangshan and the short-sea vessels, and for domestic vessels. Secondly the total need quay length is determined and compared to the already existing quay length. Thirdly the needed storage area is determined. The section will end with a conclusion of all needed dimensions of the port of Nanjing in 2005.

Determination of needed berths in 2005

River-Trade Berths

As the calls to the terminals are known a first approximation of the needed number of berths for the port is based on the equation for utilisation of the berths which is given by:

$$u = \frac{l}{m * n} \qquad \text{With} \qquad (9\text{-}2)$$

u	=	Utilisation
?	=	Arrival rate
µ	=	Service rate
n	=	Number of berths

The *arrival rate* is determined by calculating the total number of calls per year. These can be received from section 9.4. In 2005 14 river-trade calls per week will be made. With being operational 51 weeks per year 714 calls will be made per year. Therefore ? = 714 calls per year for the river trade berths.

The *service rate* is the maximum number of vessel services that can be achieved in the operational hours of the port. Therefore the average service time per vessel is needed. This is determined by the 'parcel size' which is the number of containers unloaded and loaded per call, the gross crane productivity and the numbers of cranes per berth. The two latter are known for the port of Nanjing while the normative parcel size has to be calculated from the figures in section 9.2.

The average parcel size for river-trade vessels is determined by taking the mean value of the number slots of liner services to Shanghai and Yangshan and of short-sea services.

In 2005 (See section 9.4.1 to 9.4.3)
- From Shanghai 11 calls are made with 1750 TEU per trip
- From Yangshan 1 call is made with 970 TEU per trip
- From Short-sea 2 calls are made with 1672 TEU per trip

Together this gives a mean parcel size of:

$$\frac{(11*1750)+(1*970)+(2*1672)}{(11+1+2)} = 1683 \text{TEU}$$

Per hour 50 TEU can be handled with two cranes and a gross crane production of 25 moves per hour. Therefore the handling of a mean parcel takes

$$\frac{1683}{50} = 33.7 \text{ hours}$$

With the port being operational for 51*7*24 = 8568 hours per year the maximum number of provided services (μ) per year is

$$\frac{8568 hours}{33.7 hours} = 254.2$$

When the berth utilisation is assumed to be 0.5 the needed number of berths in 2205 for the port of Nanjing can be received from:

$$0.5 = \frac{l}{m*n} = \frac{714}{287.5*n}$$

A more precise calculation can be made when the queuing theory is applied. In the situation of Nanjing the arrival process as well as the service process can be approached with an Erlang distribution.

When the equation above is used n becomes 5.6. Consequently with this utilisation the number of berths is 6 for the river-trade vessels.

In 2005 the number of needed River-trade berths for Nanjing is 6

With the number of berths being known the berth productivity can be calculated. The berth productivity[12] (C_b) is given by

$$C_b = p * f * N_b * t_n * m_b \qquad (9\text{-}3)$$

In which:

C_b	=	average annual number of TEU per berth	(TEU/year)
P	=	gross production per crane	(moves/hour)
F	=	TEU factor	(-)
N_b	=	number of cranes per berth	(-)
t_n	=	number of operational hours per year	(hours/year)
m_b	=	berth occupancy factor	(-)

For the berths for liner vessels to Shanghai and Yangshan the gross production per crane is 25 moves per hour and the TEU factor is 1.5. Per berth two cranes are found and the port of Nanjing is serving 24 hours a day, 51*7 days a year. The berth occupancy factor is according to the calculations above 0.5. With these data the berths for liner vessels and short-sea vessels have a berth productivity of 321,300 TEU per year.

Domestics Berths

The domestic vessels call 40 times per week in 2005. Per year this gives 2040 calls at Nanjing. This gives ? = 2040 calls per year for the domestic berths.

The mean parcel size can directly received from the table in section 9.4.4. With 40 calls carrying 204 TEU per trip. Handling of a parcel takes

[12] [17]

$$\frac{204}{20} = 10.2 \text{ hours}$$

with a gross crane productivity of 20 moves per hour and with one crane per berth. The maximum number of services per year is

$$\frac{8568 hours}{10.2 hours} = 840$$

When the berth utilisation is assumed to be 0.5 the needed number of berths in 2005 for the port of Nanjing for domestic vessels can be received from:

$$0.5 = \frac{l}{m * n} = \frac{2040}{840 * n}$$

With this utilisation the number n is 4.86 and therefore the required number of berths is 5 for domestic vessels.

The port of Nanjing needs in 2005 for domestic vessels 5 berths to serve all calls.

The determination of the berth productivity of the berths domestic vessels is the same. Only the moves per hour of the crane and the number of cranes deviate from the previous berths. The gross production per crane is 20 moves per hour and per berth one crane is available. With these data the domestic berths have a berth productivity of about 129,600 TEU per year.

Determination of the needed quay length in 2005

River trade berth quay length

Now the total required number of berths is known the needed quay length can be determined and compared to the already available length. The quay length calculation is based on the length of the design vessels. For the river trade berths in 2005 the vessel with a capacity of 969 TEU is normative with its length of 159 metres.

The expression for quay length[15] is

[13] [17]

[14] [17]

L_q = 1.1 * n * (L_S + 15) +15 with *(9-4)*

L_q	=	average vessel length	(m)
n	=	number of berths	(-)
L_S	=	average vessel length	(m)

This equation allows a berthing gap of 15 m between the vessels and at the outer berths also 15 metres is added. The total required quay length for river trade berths is 1163.4 metres.

Domestic berth quay length

For the domestic vessels with a length of 60 metres a gap of 15 might be too much. Therefore the assumption is made that the average berth length is 70 metres. For the domestic vessels therefore the expression of quay length will be

$L_{q,\ domestic}$ = 1.1 * n * (L_S + 10) +10 *(9-5)*

The total required quay length for domestic trade is 395 metres.

The port of Nanjing needs in 2005 1163.4 m quay length for river trade vessels and 395 m for domestic vessels. Together this is 1,558.4 metres.

According to section 9.1 in 2005 the total berth length is already planned to be 1,320 metres with the current plans. With Nanjing port becoming a transshipment port some extra quay length as in total 1,558.4 m is needed. For 2005 the port of Nanjing has to construct 238.4 m of extra quay length.

Determination of required storage area in 2005

For the determination of the area required for storage the following equation[16] is used:

$$O = \frac{Ci * td * F}{r * 365 * mi} \quad \text{with} \qquad (9\text{-}6)$$

[15] [17]

[16] [17]

O	=	required area (m^2)
C_i	=	number of container movements per year
T_d	=	average dwelltime (days)
F	=	Required area per TEU inclusive equipment travelling lanes
r	=	average stacking height
m_i	=	acceptable average occupancy rate (0.65 to 0.70)

the number of container movements in 2005 is 1.616 mTEU and the dwelltime of Nanjing is assumed to be 7 days which is for inland terminals a mean dwelltime. The stacking height and Nanjing is 3 and the occupancy rate is 0.65. As F[17] is 13 m^2 the total required storage area for 2005 at Nanjing port can be determined and is 206,612 m^2 or 455mx455m.

Conclusion for 2005

In 2005 the port of Nanjing needs 6 river trade berths and 5 domestic berths to be able to handle all calls at the port. For 2005 the presence of 5 large berths is already planned. However, only 2 berths for domestic vessels are currently planned.

The total needed quay length is 1,558.4 m. Currently, the plans contain 1,320 m and therefore the port of Nanjing has to construct 238.4 m of extra quay length. This should especially be used for the domestic berths.

The total needed storage area of Nanjing Port in 2005 is 455mx 455m.

9.5.3. Dimensions of the port for 2010

Determination of needed berths in 2010

River-Trade Berths

Also for 2010 the calls to the terminals are known and a first approximation of the needed number of berths for the port is received with the equation for utilisation of the berths which is given by (9-2).

Arrivals

[17] [17]

In 2010 15 river-trade calls per week are expected. With the terminal being operational 51 weeks per year in total 51*15 =765 calls will be made per year. Therefore for the river trade berths for 2010 ? = 765 calls per year.

Service

Also for 2010 the mean parcel size is determined by taking the mean value of the number of occupied slots per trip of liner services to Shanghai and Yangshan and of short-sea services.

In 2010 (See section 9.4.1 to 9.4.3)

- From Shanghai 10 calls are made with 1686 TEU per trip
- From Yangshan 4 calls are made with 1730 TEU per trip
- From Short-sea 3 calls are made with 1490 TEU per trip

Together this gives a mean parcel size of 1662 TEU. With the same gross crane production as in 2005, two cranes per berth and the same operational hours the handling of a parcel takes 33.24 hours while µ is 258.

Number of berths

When the berth utilisation is assumed to be 0.5 the needed number of berths in 2205 for the port of Nanjing can be received from:

$$0.5 = \frac{l}{m * n} = \frac{765}{258 * n}$$

Resulting from the equation above n is 5.93 and therefore 6 berths are needed. The utilisation of 0.5 should be used in the calculation of the berth productivity given by (9-3) which is 321,300 TEU per berth.

In 2010 the port of Nanjing needs 6 berths for the river trade vessels

Domestics Berths

arrivals

In 2010 domestic vessels make 47 calls per week. This is per year 2397 calls at Nanjing. Therefore ? = 2397 calls per year.

services

With 47 calls carrying 205 TEU per trip the parcel size is known. With one crane with a capacity of 20 moves per hour the handling of a parcel takes 10.25 hours. Resulting µ is 836 when the operational hours are not changed compared to 2005.

Number of berths

With the assumed utilisation of 0.5 the needed number of berths in 2010 for the port of Nanjing for domestic vessels can be received from:

$$0.5 = \frac{l}{m * n} = \frac{2397}{836 * n}$$

Resulting n= 5.7 and therefore the required number of berths is 6 for domestic vessels. The final u will be 0.48. With this utilisation the berth productivity is 123,340 TEU.

6 berths for domestic vessels should be available in 2010 at the port of Nanjing to handle all calls.

Determination of quay length in 2010

With (9-4) and (9-5) the quay length can be determined. The needed quay length for river-trade is 1163.4 m. For domestic berths this is in 2010 477 m. In total a quay length of 1610.4 m is required.

In 2010 Nanjing port needs a total quay length of 1640.4 m with 1163.4 m for the berths of the river trade vessels and 477 m for the domestic berths

Determination of required storage area in 2010

With equation 9-6 the total required storage area can be determined as C_i is in 2010 1.932 TEU and all other factors are the same as in 2005. The total required storage area is 247,014 m^2 or 497m x 497m.

Conclusion for 2010

For the year 2010 the port of Nanjing needs 6 river transport berths and 6 domestic berths. As in 2005 a quay length of 1558.4 was needed and assumed to be constructed the extra quay length to construct between 2005 and 2010 is only 82 metres with the needed quay length in 2010 of 1640.4. This should be used for an extra domestic berth.

The total needed storage area is 247,014 m2 (497x497). In 2005 the storage area was 455x455 to between 2005 and 2010 an extra storage yard of 200m x200m is needs to be constructed.

9.5.4. Dimensions of the port for 2020

Determination of needed berths in 2020

River-Trade Berths

The number of berths is determined by using equation (9-2).

Arrivals

In 2020 24 calls of river-trade vessels are expected at Nanjing Port per week. Per year this is 1224 calls. Therefore ? is 1224 calls per year.

Service

The determination of the mean parcel size is equal to the approach in section 9.5.2 and 9.5.3.

In 2020 (See section 9.4.1 to 9.4.3)
- From Shanghai 9 calls are made with 1668 TEU per trip
- From Yangshan 11 calls are made with 1787 TEU per trip
- From Short-sea 4 calls are made with 1681 TEU per trip

18 [17]

Together this gives a mean parcel size of 1725 TEU. When the gross crane production as is 25 moves per hour and at each berth two cranes are found the handling of a parcel takes 34.5 hours. And when the port is operating 51 weeks per year and 24 hours a day the value for µ is 248.4.

Number of berths

The determination of berths follows from:

$$0.5 = \frac{l}{m * n} = \frac{1224}{248.4 * n}$$

With an utilisation-value of 0.5 n becomes 9.86. Ten berths are needed to serve all vessels with a maximum utilisation of 0.5. The actual u with 10 berths is 0.49. This utilisation should be used in the calculation of the berth productivity given by (9-3) which is 273,100 TEU per berth.

In 2020 10 berths are needed for the river trade vessel handling at Nanjing.

Domestics berths

arrivals

In 2010 domestic vessels make 68 calls per week. This is per year 3468 calls at Nanjing. Therefore ? = 3468 calls per year.

services

With 68 calls carrying on average 207 TEU per trip and with one crane with a capacity of 20 moves per hour the handling of a parcel takes 10.35 hours. Resulting µ is 827.8 when the operational hours are not changed compared to 2005.

Number of berths

With the assumed utilisation of 0.5 the needed number of berths in 2010 for the port of Nanjing for domestic vessels can be received from:

$$0.5 = \frac{l}{m * n} = \frac{3468}{827.8 * n}$$

Resulting n= 8.34 and therefore the required number of berths is 9 for domestic vessels. The final u will be 0.47. With this utilisation the berth productivity is 119,649 TEU.

For domestic vessel service in 2020 9 berths are needed at the port of Nanjing.

Determination of quay length in 2020

With (9-4) and (9-5) the quay length can be determined. The needed quay length for river-trade is 1929 m. For domestic berths this is in 2010 703 m. In total a quay length of 2632 m is required.

MERGEFORMAT

Determination of required storage area in 2020

As C_i is in 2020 2.829 TEU with equation (9-6) the total required storage area can be determined as all other factors are the same as in 2005. The total required storage area in 2020 is 361,786 m^2 or 601m x 601m.

Conclusion for 2020

In 2020 10 river trade berths and 9 domestic berths are required. Together this gives a quay length of 2632m. With in 2010 a quay length of 1640.4m between 2010 and 2020 991.6 m of extra quay length should be constructed.

With a required storage yard of 361,786m^2 (601mx601m) while this was in 2010 247,014m2 (497mx497m) the storage area should be increased with 114,762 m^2 (339mx339m)

All result are together represented in the table below.

	2005	2010	2020
river berths	6	6	10
domestic berths	5	6	9
total required length (m)	1558	1640	2632
length to construct (m)	238	82	992
total storage area (m2)	455x455	497x497	601x601

9.6. Conclusions Port of Nanjing

- With the strong position of Nanjing Port it will see its throughput increase as the number of calling vessels is rising. Four kind of calls are made at Nanjing Port: sea-river transport calls from Yangshan Port, river transport calls from Shanghai, short sea calls and domestic call from ports upstream of Nanjing.

- Before the number of calls at Nanjing can be determined the dimensions of the design vessels are determined. These are depending on the depth of the river mouth that is determined by the phase of dredging and the use of the tide.

- For the accessibility of Nanjing Port the depth required at the river mouth is maximum 10.5 m. Dredging phase three is therefore not needed for transport over the Yangtze River to Nanjing.

- Vessels coming from Yangshan, Shanghai and short-sea all use the same berths at Nanjing. In 2005 they make together 14 calls per week while in 2020 the number of weekly calls increases to 24. The domestic vessels call in 2005 40 times per week and in 2020 this is 68 times.

- Because of the high container volumes between Nanjing and the other ports liner trade is an option to regulate the transports with a high reliability as advantage.

- The number of design vessels needed for the liner services is 7 in 2005 and in all other years of the prognoses the required number is six. Yangshan needs 1 vessel for liner services to Nanjing in 2005. In 2020 this increases to 8 design vessels.

- To be able to handle the increasing number of calls Nanjing needs in 2005 in total 11 berths. Compared to the already existing expansion plans an extra quay length of 239 m is required.

- In 2010 the total number of needed berths is 12. Compared to the quay length of 2005 the port of Nanjing needs the construction of 52 m extra quay length. Compared to 2005 the required area for storage should be increased with 200mx200m.

- In 2020 the number of berths increases to 19. Consequently also the quay length strongly increases with 1022m compared to 2010. The storage area needs an extra of 339mx339m compared to 2010.

- The conceptual dimensioning made in this chapter is an indicator for the future dimensions of the port of Nanjing further investigation is necessary. More precise dimensions of the wet and dry infrastructure are needed. As Nanjing is an open water port an investigation of the sedimentation process should be part of this. Also more precise characteristics of the used equipment should be determined.

- With Nanjing being an open water port the sedimentation should be determined

- To determine the exact location of the terminals in the future more information about the current situation at Nanjing is needed.

Port of Nanjing in 1990

10. Conclusions & Recommendations

10.1 Conclusions

- As the Chinese economy is undergoing a strong growth, even further strengthened by the Chinese membership to the WTO and the attractiveness for foreign investors caused by the low labour costs and the world wide continuing globalisation, the Chinese share to the world total container throughput is increasing every year. In 2001 it was 9.3%, for 2002 13% is expected. It can be said that the Chinese economy is ‘booming’.

- Shanghai Port strongly exceeds the average worldwide growth in container throughput and is facing a capacity problem. The current capacity is expected to be stretched to its maximum around 2003 while Yangshan becomes not operational before 2005. Preventing possible occurring delays of the construction is of great importance.

- Even when the design capacities of Yangshan Port are added to the design capacities of Shanghai, both ports need to use their capacity very efficient to keep up with the throughput growth. When the Luyang Bridge becomes unusable, because of an accident for example, Yangshan Port will not be able to function as a normal port.

- The best performing transportation chain between the hinterland and both ports are options transporting containers direct to an inland waterway terminal. With the depth restriction of the entrance channel of Shanghai Port and its limited capacities, direct transport from and to Yangshan is preferred. However, calculations show that with the expected modal split, it is not until 2015 that both ports transport almost equal volumes over the Yangtze River as until then Shanghai Port dominates the transported volume.

- From the MCA can be concluded that transport from Yangshan Port by truck without transfer at Luchao Harbour City (option3) is the most competitive option to direct transport to an inland terminal. To strengthen the position of inland shipping, the Chinese fleet should be expanded with larger vessels to offer a good economy of scale. Inter-modal transport should be stimulated and the facilities at the terminals along the Yangtze should be improved to become more efficient. In this way the Yangtze River can be used to push the economic development from the east coast to the more western provinces of the country.

- Nanjing can become the linking port of the Yangtze River's middle and lower reaches. It offers a good location for a transshipment port according to the calculated container flow over the Yangtze River.

- Regulating the transports between Nanjing and the coastal ports Shanghai and Yangshan will result in high reliability. This regulation can be realised by employing liner services. The number of calls from Shanghai is slightly diminishing from 11 per week in 2005 to 9 in 2020. The number of calls from Yangshan however is strongly increasing from 1 per week in 2005, assuming the port becomes operational by then, to 11 per week in 2020.

- As the contribution of Shanghai to the transported container volume over the Yangtze River is high, it might be preferable to make only calls from Shanghai and none from Yangshan as long as the contribution of the latter is low. As in practice it is probably not possible to let all containers with destination Yangtze river arrive at Shanghai and not at Yangshan, transport option 5 (transport via Yangshan to Shanghai and further to an inland waterway terminal) might be interesting to use as long as the volumes are rather low, even though the score of this option in the MCA was low.

- To contribute to the accessibility of Nanjing Port the required depth at the river mouth is 10.5 m. as the river section between Wusong and Nanjing is of the same depth. Dredging phase three is therefore not needed for transport over the Yangtze River to Nanjing.

- To be able to handle the increasing number of calls Nanjing needs a total of 11 berths in 2005. In 2010 the total number of required berths is 12. In 2020 the number of berths increases to 19. Frequent construction of extra berth length is required when Nanjing becomes a port of transshipment.

10.2 Recommendations

- It is concluded that for the hinterland transport over the Yangtze River phase 3 of the dredging programme is not needed. For the port of Shanghai, however, it might be useful to deepen the entrance channel further. Therefore it should be investigated whether and when phase 3 of the dredging programme is necessary for the port of Shanghai.

- Further investigations should be done into the usage of option 5 when the transported container volumes over the Yangtze are still relatively low. Also the navigation and mooring conditions for liner services calling at Yangshan should be determined.

- The calculation of the number of calls to Nanjing port is based on the ratio of import and export of 48% to 52% according to the Chinese water design institute. The sensitivity to this ratio should be taken into account for the long- term development of the port.

- As the global dimensioning is an indicator for the future dimensions of the port of Nanjing, further investigation is necessary. More precise dimensions of the wet and dry infrastructure are needed. As Nanjing is an open water port an investigation of the sedimentation process should be part of this. Also more precise characteristics of the used equipment should be determined. For the rail and road transport to and from Nanjing the required facilities and capacities should be determined.

- Further investigation into the costs is required. A comparison should be made between the cost reduction caused by the economy of scale of vessels transporting containers to Nanjing and the costs of the construction of extra berths. Also an actual calculation of the cost differences between truck transport from Yangshan and inland navigation should be made, as this truck transport is the main competitive transportation chain.

- To reduce the number of calls and the accompanying costs it might be useful to investigate the use of barges. The services time at the terminals can be reduced and also the turn around time will diminish.

- More investigations should be made into the characteristics of the Yangtze River.

Bibliography

[1] **d'Angremond Prof ir.K.** (1998), *Coastal Engineering Volume I*, Delft

[2] **Blauwens G., De Baere p., Van de Voorde E.** (2001), *Transport Economics*, Antwerpen

[3] **Containerisation International** (2002), *Yearbook 2002*, London

[4] **Deutsche Verkehrs Bank** (2002), *The Container Market and its Outlook*, Germany

[5] **Delta Marine Consultants** (2002), *Yangshan Container Port, Concept Design, Closure Dam*, Gouda.

[6] **DHV Milieu & Infrastructuur** (1991), *Onderzoek Overslag Binnenvaart*, Amersfoort.

[7] **Drewry Shipping Consultants** (1999), *China, Opportunities and Challenges for World Shipping*, London, England

[8] **Drewry Shipping Consultants** (2002), *Annual Container Market, forecast and review-2002*, London, England

[9] **Economische Voorlichting Dienst** (2002), *China: landenorientatie*, Den Haag

[10] **Edge B.L.**(1999), *Coastal Engineering Volume III,* New York

[11] **Groenveld ir R.**(1999), *Capacities of Inland Waterways*, Delft

[12] **Groenveld ir R.**(2002), *Service Systems in Ports and Inland Waterways*, Delft

[13] **van Holst & Koppies** (1998), *Kansen op het traject short sea shipping – binnenvaart*, Capelle ad IJssel.

[14] **Huybrechts M.** e.a. (2002), *Port Competitiveness, an economic and legal analysis of the factors determining the competitiveness of seaport*, Antwerpen.

[15] **ING Barings** (2001), *Radar, Asian Transport & Logistics Strategy*, Amsterdam.

[16] **Kai Yan** (2001), *Regulation of deep navigation waterway in the Yangzte River Estuary*, Nanjing, China

[17] **Ligteringen Prof. Ir. H.** (2000), *Ports and Terminals*, Delft

[18] **Lee T.W., Roe M., Gray R., Shen M.** (2002), *Shipping in China*, Ashgate

[19] **Luo M., Grigalunas T.A.** (2002), *A spatial-economic multimodal transportation simulation modal for US coastal Container Ports*, Kingston, USA

[20] **Ministry of Communications of the people's Republic of China** (1990), *China's Principal Ports for foreign Trade*, Beijing, China

[21] **Nationale Havenraad** (2001), *Nederland Havenland: de Nederlandse zeehavens in economisch perspectief*, Den Haag.

[22] **NEA transportonderzoek en –opleiding** (1994), *Beleids Informatie Systeem Binnenvaart, de capaciteitssituatie in de periode 1992 t/m 1999*, Rijswijk

[23] **Nunen, van J., Verspui, L**.(1999), *Simlog, simulatie en logistiek rond de haven*, Delft

[24] **Pols Prof Ir A.A.**J, **Verhaeghe Ir R.**J., *Plan- en projectevaluatie deel I*, Delft, 1999

[25] **Port and Delta Consortium bv** (1999), *Yangtze Pilot Project*, Papendrecht

[26] **Platinum Brooking** (2002), *Shanghai Property Guide*, Hong Kong

[27] **Recordit** (2001), *General Methodological Framework for accounting real costs of inter-modal transport*, Italy

[28] **Riemslag C.** (2001), *Container terminal development port of Shanghai*, Delft

[29] **State Planning Commission China and Ministry of transport, Public works and Water Management** (1998), *Masterplan Study Report, Sino-Dutch joint research on the Yangtze River Basin inter-modal transport project*, Nijkerk

[30] **Third Harbour Engineering Investigation & Design Institute** (2001), *Shanghai Chemical Park Vopak Harbor Co. LTD. Chemical Terminal project*, Shanghai, China.

[31] **Toen-Gout, MW, Jongeling MM** (1994), *Investments in infrastructure and economic growth*, Den Haag.

[32] **Tong Jiang** (1999), *Analysis of flood hazards in the Yangtze river valley and strategies for sustainable flood risk management*, Giessen.

[33] **United Nations** (2001), *Economic and social commission for Asia and the Pacific, Review of developments in transport in the Escap Region 1996-2001*, New York

[34] **Voorde van de E, Winkelmans W.** (2002), *Port Competitiveness, an economic and legal analysis of the factors determining the competitiveness of seaports,* Antwerpen

[35] **Welters Prof H.W.H. ea** (2002), *Port Economics,* Rotterdam

[37] **World Bank** (1999), *Port Reform Tool Kit,* USA

[38] **World Bank** (1997), *China Inland Waterways II, IWW transport sector development strategy study,* USA

Journal of Transport Geography

[39] **Loo B.P.Y.,** (1999-7) *Development of a regional transport infrastructure: some lessons from the Zhujiang Delta*, *Guangdong, China,* Hong Kong, China

[40] **Rissoan J.P.** (1994-2), *River-sea navigation in Europe*, Lyon France

[41] **Wang, J.J,** (1998-3), *A container load centre with a developing hinterland: a case study of Hong Kong*, Hong Kong

[42] **Wang J.J., Slack B.** (2000-8), *The evolution of a regional container port system: The Pearl River Delta*, Hong Kong, China

Magazines

[43] **Cargo Systems Asia** 2002-2003

[44] **Containerisation International** August 2002

[45] **China Daily**

[46] **De Lloyd** June 2002

[47] **Hansa,** May 2003

[48] **NTDosier, China Japan & Korea**, February 2003

[49] **Ports and Harbors** June 2002

Internet

[50] **www.ci-online.co.uk**

[51] **www.eia-ngo.com**

[52] **www.enricomusso.it**

[53] **www.evd.nl**

[54] **www.inlandshipping.com**

[55] **www.itmma.ua.ac.be**

[56] **www.port- technology.com**

[57] **www.tdctrade.com**

Appendices

I. Additional information about China

In the figure below the representative figures for the Chinese population are given

		2000	2005	2010
Population (million)	Total	1,265,00	1,319,30	1,366,10
	Man	651.4	677.1	701.1
	Woman	614.3	642.2	665.0
Age structure (%)	0-14	24.9	21.9	20.3
	15-64	68.3	70.6	72.0
	65+	6.8	7.5	7.7
		1996-00	**2001-05**	**2006-10**
Life expectancy	Man	67.9	69.1	70.2
	Woman	72.0	73.5	73.9
	Average	69.8	71.2	72.0
Averages per annum	Growth population (%)	1.0	0.8	0.7
	Growth working population %	1.2	1.1	0.8
	Birth rate (per 1000)	16.2	14.6	14.0
	Mortality rate (per 1000)	6.9	7.0	7.4
	Migration rate (per 1000)	-0,1	-0.1	-0.1
	Infant mortality (per 1000)	41.0	36.0	28.0

A. Figure 1 characteristics Chinese Population

II Additional information about the South-Eastern Provinces

The provinces along the Yangtze River that can be reached by vessel are, going up stream Shanghai Municipality, Jiangsu, Anhui, Jiangxi and finally Hubei. All of these provinces are of importance for the development of container transport over the Yangtze River as they have lots of economic activity and further growth is expected. In this appendix beside information about these five provinces also some information is given about the province Zhejiang as this province is of great importance for the Chinese economy.

Shanghai Municipality

Throughout the centuries, Shanghai has been China's most important industry and trade centre. Not very surprising because Shanghai, which means 'by the sea', has a very unique geographical position. It is located along the Huangpu River and at the mouth of the Yangtze River. In 1842 the British started to influence Shanghai which was by then a small town supported mainly by fishing. It was successful, Shanghai turned out to be the wealthiest region of China. Beside during the communistic period foreign companies have always had dependencies in Shanghai. During the nineties the Chinese government decided to develop Shanghai into an important financial centre which should be able to compete with Hong Kong. The mean yearly income of Shanghai is about four times higher than the income of the poorest region of China, Gansu Province. The city continues to grow with new underground stations, highways criss-crossing the city, a modern stock exchange and cultural institutions. In Shanghai the industry produces mainly petrochemical products, electronics, iron, steel, heavy machinery and cars. A part of these products is meant for export, but also the hinterland of Jiangsu Province and Zhejiang Province are customers. Even though the industry is very important, the tertiary sector which are the services, have also grown very much.

The port of Shanghai can be seen as a gate to the flourishing and booming economy of Shanghai and its hinterland. Shanghai has the largest container port of the mainland of China. The terminals of the port are operating 24 hours per day, to support the development of the economy as good as possible.

Jiangsu Province

Jiangsu is a fertile area with the Yangtze River providing of water. As most fertile areas do, Jiangsu also attracted a lot of people in the past. Now it is one of the most populous provinces of China with high industrial productions as a positive result. Main products are machines, fabric and electronics. Jiangsu has a widespread inland waterway system and has several ports like Nanjing, Zhangjiagang and Nantong Port. Thanks to its natural navigation channels Nanjing Port has a very favourable position. It has currently two dedicated container berths. Zhanjiagang Port achieved its position by being located in a well-developed part of Jiangsu province and has currently two dedicated containerberths. The development of Nantong, on the north bank of the Yangtze River is a slower but with its good natural conditions it has a good potential for the future.

The roads in the province are very well maintained and together with the nine airports of the province, it can be said that the infrastructure in Jiangsu is very well developed. This can be of good use to support the economic and trade development which is currently comparatively a little backward.

Anhui Province

Of the province Anhui is Hefei the capital. It is also the main business, trade, information and finance centre of Anhui. Its main industries are electronics, machinery, and chemistry.

The main port of Anhui is Wuhu Port. Currently there are two container handling terminals. The catchment area of Wuhu will probably be enlarged in the future. Because of its facilities the potentials for this port are quite good. Other ports of importance in Anhui are Anqing and Tongling. In and around Anqing the major industries are large-scale petrochemistry and building materials. But the container volume in Anhui Province is mainly generated in Hefei and Wuhu area. About 80% of the total container volume of Anhui is generated in the Wuhan and Hefei areas. Especially Wuhu has a good transport condition.

Jiangxi Province

The province Jiangxi has an important transport function between the province Guangdong and the more inland provinces of China. Half of Jiangxi is covered with trees and consequently the province is specialised in production of wood and bamboo. Besides the production of wood, the last decades also the industrial development became important. Especially production of paper and chemical industry is coming up. To attract investors from Taiwan also Special Economic Zones are created.

The main port of Jiangxi is Jiujiang Port which has good transport conditions and currently two dedicated container berths. It is located nearby the well-developed regions in Jiangxi. The container production of Jiujiang area, Nanchang area and Jingdezhen area, see map of Jiangsu, is a growing business and has a great potential for the future.

Hubei Province

The province Hubei is splitted by its geography in two parts. The Yangtze River and the Han River cross the eastern part while the western part is much rougher and only has some cultivated valleys. In Hubei, large amounts of chemicals and building materials are produced. The main export products are steel and cars.

The capital of Hubei is Wuhan and is situated on a central point along the Yangtze. This gives Wuhan the position to become a transportation and distribution centre. With its great catchment area Wuhan is well developed in economic and trade. Still there is potential for further development. Other ports in Hubei, Huangshi port, Shashi port and Yichang port (See map of Hubei) are of a much smaller scale than the port of Wuhan.

A little upstream from Wuhan the 'Three Gorges Dam' is being built. The area around Wuhan can benefit from the economic consequences as this dam attracts a lot of investments in the infrastructure and in the power plant which is built nearby the dam. As soon as the dam and the power plant are operational, Hubei will start exporting electricity.

Zhejiang Province

Zhejiang is the smallest, wealthiest and most powerful province of China. It has a long history of trade, mainly caused by the fifty ports the province has. Especially the ports with a good connection to the agricultural hinterland like Hangzhou and Ningbo, have known a quick development. Looking at the economic growth, Zhejiang can be found in the top five of all the Chinese provinces. This growth is mainly caused by the trade sector although the agriculture is the core economic activity of the province. Main export products are shoes, clothing and plastic.

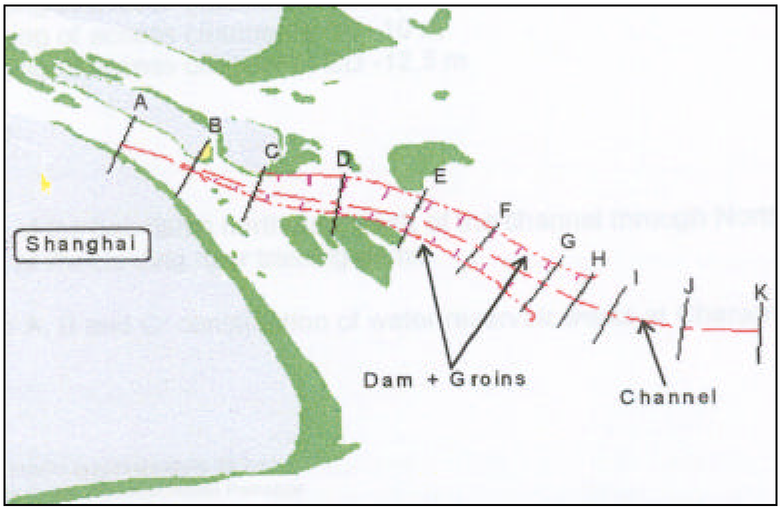
The largest seaport in Zhejiang Province is Ningbo. It handles large volumes of bulk cargo transshipment for Shanghai and places and places along the middle and lower reaches of the Yangtze River. The second port of Zhejiang is Wenzhou. It is a foreign trading port and maintains a close shipping contact with Shanghai and Ningbo.

I. III Maps Yangzte River Mouth

II. IV Satellite Photo’s River Mouth

V Dredging Volumes

From the Yangtze Pilot Project [25] the dredging volumes for the entrance channel can be derived. The entrance channel is divided into sections from A to K as can be seen from the Figure below.



SEQARABIC In the table below the volumes of dredging are given for all sections and for the all three dredging phases.

Section	Dredging to CD-8,5m		Dredging to CD-10m		Dredging to CD-12,5m	
	Capital mln m3	Maintenance mln m3/year	Capital mln m3	Maintenance mln m3/year	Capital mln m3	Maintenance mln m3/year
AB	1.6	0.0	5.4	0.0	14.3	0.0
BC	0.9	0.0	3.5	0.0	12.2	0.0
CD	9.8	1.2	15.3	1.5	25.6	0.4
DE	8.2	3.1	13.0	3.8	22.8	2.1
EF	10.9	9.3	5.1	10.8	14.1	9.3
FG	2.5	8.5	7.5	10.0	16.7	13.0
GH	2.0	0.8	4.6	1.0	9.5	5.4
HI	0.4	0.0	3.0	0.0	8.3	2.5
IJ	0.0	0.0	1.7	0.0	11.6	5.9
JK	0.0	0.0	0.0	0.0	3.1	3.1
Total	26.6	23.0	58.4	27.0	138.3	41.8

The bottom depth in between the river dams will be 300 m. The slopes have been assumed to be 1:10 for the capital dredging volumes.

VI Deduction Modal Split of Yangshan

The Chinese Water Design Institute (CWDI) has released its prognoses on container transport and handlings for Yangshan port. These figures are the basis for the design and investment calculations conducted by the Chinese authorities. The information, as released by the CWDI, is presented in the tables 1 and 2 below and will serve in this appendix to calculate the future modal split of Yangshan.

The forecast of container volumes over water, specified by character, is as follows:

Year		2005	2007	2010	2015	2020
Total throughput		**2,200**	**4,000**	**6,700**	**10,300**	**14,300**
of which						
	Far sea	1,600	2,950	4,750	7,050	9,300
	Near sea	60	180	450	950	1,800
	Near sea Transshipment	140	220	300	450	600
	Chinese coast	300	350	550	750	900
	The Yangtze river	100	300	650	1,100	1,700

Source: Chinese Water Design Institute

Table 1 Container volume forecast through water transportation, (x1,000) TEU

The forecast of the container volumes to be distributed is presented in the table below:

Year		2005	2007	2010	2015	2020
Total distributed volume		**1,660**	**3,130**	**5,200**	**8,000**	**11,100**
of which						
	Near sea transshipment	140	220	300	450	600
	Chinese coast	300	350	550	750	900
	The Yangtze river	100	300	650	1,100	1,700
	Railway	100	150	200	350	550
	Highway	1,020	2,110	3,500	5,350	7,350

Source: Chinese Water Design Institute

Table 2 Container volume forecast by distribution, (x1,000) TEU

The explanation of the terms used is as follows: “Far sea” are the Ocean internationall services and “Near sea” are the short sea international services. Transshipments within

Near sea have been presented separately by CWDI (and have been included in distribution). With “Chinese coast” the Coastal domestic services are meant while “Yangtze River” are the river domestic services.

From table 2 can be seen that the Near sea transshipment is counted under volume to be distributed, which can obviously be doubted (transhipped containers do not need extra distribution).

A combination of the two tables makes it possible to determine the total container flow and the accompanying modal split.

Yangshan Port, total flows					(x1,000) TEU
Year	**2005**	**2007**	**2010**	**2015**	**2020**
Total throughput	**2,200**	**4,000**	**6,700**	**10,300**	**14,300**
of which a/o Transshipment Near Sea	140	220	300	450	600
Total distributed volume	**1,660**	**3,130**	**5,200**	**8,000**	**11,100**
of which a/o Transshipment Near Sea	140	220	300	450	600
Difference ***(Transshipment water other than Near sea)***	***540***	***870***	***1,500***	***2,300***	***3,200***

Table 3 Total Container Flow at Yangshan Port

The difference between the total throughput and the total volume to be distributed can only be explained when the remaining TEUs are transshipped over water. Consequently, for 2005 the transshipment was $2{,}200 \times 10^3 - 1{,}660 \times 10^3 = 540 \times 10^3$ TEU. Even though the Chinese figures (CWDI) present the Near sea transshipment under the volumes of collection and distribution, this does not seem consistent nor correct. The total 2005 transshipment will therefore be 540×10^3 TEU + 140×10^3 TEU = 680×10^3 TEU. By knowing the total transshipment also the total distributed volume can be derived (see Table 4).

Yangshan Port, total flows						(x1,000) TEU
Year		**2005**	**2007**	**2010**	**2015**	**2020**
Total throughput		**2,200**	**4,000**	**6,700**	**10,300**	**14,300**
Transshipment water (other than Near sea)		540	870	1,500	2,300	3,200
Transshipment Near sea		140	220	300	450	600
Total Transshipment	**-**	**680**	**1,090**	**1,800**	**2,750**	**3,800**
Total distributed volume		**1,520**	**2,910**	**4,900**	**7,550**	**10,500**

Table 4 Actual Total Volume for Distribution 2005-2020

With the assumption that the ratio between the hinterland transport modes (coastal domestic services, river domestic services, rail and road services) remains the same as in Table 2, the modal split of Yangshan can be determined. The ratio between the modalities is given in Table 5 below:

Ratio	Railway :	Chinese coast :	Yangtze River :	Highway
2005	1.00	3.00	1.00	10.20
2007	1.00	2.33	2.00	14.07
2010	1.00	2.75	3.25	17.50
2015	1.00	2.14	3.14	15.29
2020	1.00	1.64	3.09	13.36

Table 5 Ratio between the hinterland transport modes

When these ratio's are converted into percentages, the modal split for Yangshan Port is the result:

Modal Split (%)	2005	2007	2010	2015	2020
Higway	67.1	72.5	71.4	70,9	70
Rail	6.6	5.1	4.1	4,6	5.2
Yangtze River	6.6	10.3	13.3	14.6	16.2
Coastal domestic	19.7	12.1	11.2	9.9	8.6
Total	100	100	100	100	100

Table 6 Modal Split of Yangshan Port

When this modal split is applied to the total volume for distribution, the *container volumes per modality* are found, which is presented in Table 7.

Yangshan Port, total flows					(x1,000) TEU
Year	**2005**	**2007**	**2010**	**2015**	**2020**
Total throughput	**2,200**	**4,000**	**6,700**	**10,300**	**14,300**
Total Transshipment	680	1,090	1,800	2,750	3,800
Total volume for distribution	**1,520**	**2,910**	**4,900**	**7,550**	**10,500**
among which					
Chinese Coast	300	352	549	748	903
Yangtze River	100	300	652	1,102	1,701
Railway	100	148	200	347	546
Highway	1,020	2,110	3,499	5,353	7,350

Table 7 Container Volumes per modality for 2005-2020

III. VII. Map transport network

IIX Terminal Process

The various alternative solutions to transport containers to and from the hinterland of Yangshan and Shanghai can also be presented schematically. When looking at the transport from Yangshan to the hinterland, every alternative commences with transport by a certain modality followed by handling at a terminal. Depending on the routing of the containers, this process can be repeated up to three times before the final hinterland transport delivers the container at its destination.

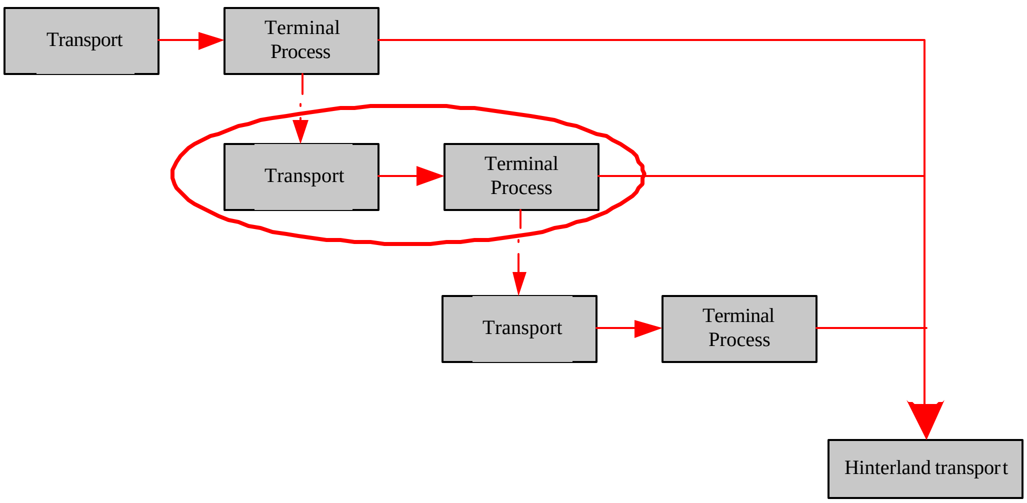


Figure 2

A transport, regardless of the used modality, is invariably followed by a terminal process as can be seen from Figure 1. Therefore the transport module and the terminal process together could be presented as one entity. However, before this can be done, first the 'black box' approach of the terminal process should be counteracted.

Terminal process

The advantage of the 'black box approach' of the terminal process is the fact that it is clear that the input and the output of the system are equal. However, the time interval is in order of months because the dwell time of containers must be included. But when disentangling the terminal process, nothing is changed in terms of container flow.

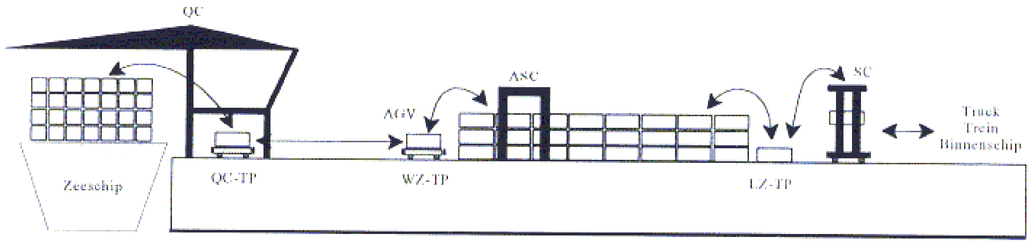
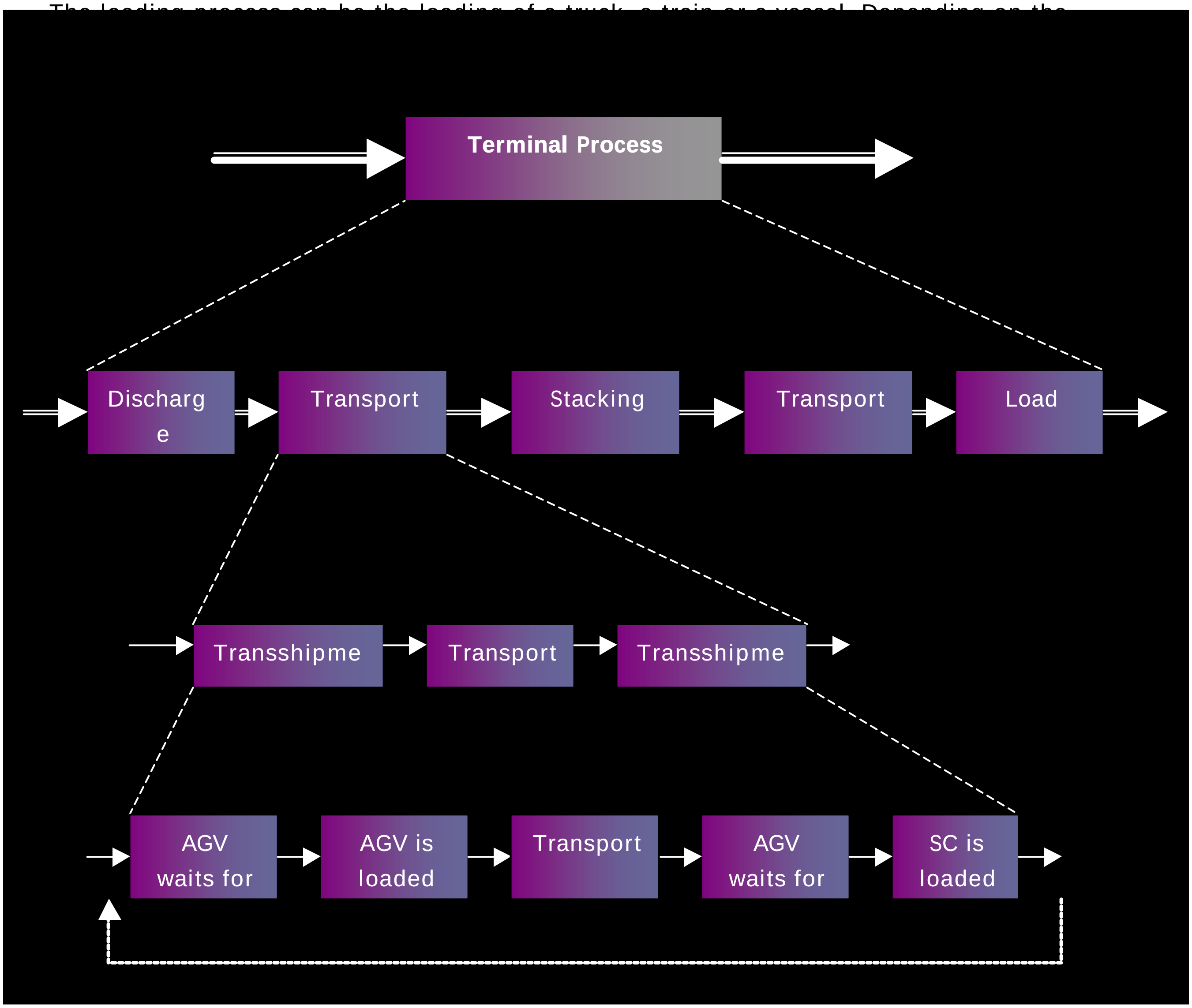


Figure 3

Initially the terminal process can be divided into five main-activity modules:

- Discharge
- Transport from quay to stack
- Stacking
- Transport from stack to rail-, road or barge service centre
- Loading

The loading process can be the loading of a truck, a train or a vessel. Depending on the



Transport modules for Shanghai Port and Yangshan Port

Based on the unravelling of transportation chains used for hinterland transport from Yangshan Port and Shanghai Port and vice versa, the chains can be divided into 7 transport modules. It can be seen that differences can be made between the haulage modalities and that the actual delivery of the container to its destination can be treated as a separate module. Also becomes visible that the marshalling process and the terminal process should be dispersed in order to be able to obtain comparable transportation chains.

	Transport module
1	Actual hinterland transport
2	Pre/post haulage Road
3	Pre/post haulage Rail
4	Pre/post haulage Inland Waterways
5	pre/post haulage Short Sea
6	Marshalling process
7	Terminal process

Table 5

After passing transport module 7 and 8 a choice can be made between the modules 3, 4, 5 and 6 or a combination of these. In case a combination is made, also module 7 and 8 are included again as can be seen from Figure 1. Because of the fact that short sea is also mentioned as a hinterland transport mode, it is here mentioned as a way of pre/post haulage while sea-river transport is placed under pre/post haulage via inland waterways. In that case addition of an extra terminal process is not necessary.

By linking the required transport modules, all possible transportation chains for the hinterland transport of Yangshan and Shanghai can be formed. The benefit of the division into transport modules is the fact that the total transportation chains, regardless of the modality used, are now comparable.

IV. IX. Eight Transport Options

X. Cost and Time Approach of a transportation Chain

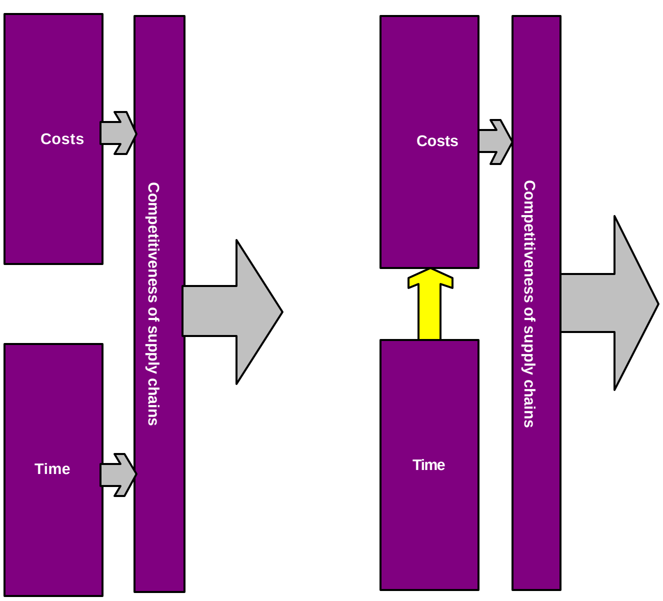
The base for the comparison of the competitiveness of the transportation chains or transport modules, is given by two factors

- Time
- Costs

For the analysis of the cost situation of the inter-modal transportation chains, all arising cost items in a transportation chain need to be identified. Ascribing costs to the defined transport module gives the opportunity to determine the total costs of a transportation chain.

Time and cost

A top down approach of the competition issue starts with the principle that choosing between transport modes is based on differences of costs throughout the total chain. So, in order to fulfil this principle, it is necessary to express also the factor time in costs.



Time can be seen as an internal cost factor as well as an external cost factor. When time is approached as an internal cost it is considered as the time required for the transport. When time is approached as an external cost, the time costs made by other users of the same infrastructure because of this added vehicle are meant: congestion is an example. For freight transport the main components of time costs are, according to Recordit [1]:

- Inventory costs
- Costs which measure the loss of value of the goods transported as a result of the duration of the trip.

Inventory costs come into being when goods are being transported. During this transportation time they do not generate an added value, and therefore generate a financial cost to its owner, which is usually estimated on the basis of standard discount rates.

Loss of value is created by the fact that a customer is waiting for its goods. Goods are transported for the benefit of the customer, who needs the cargo as input for a further value-added-generating process. When the cargo is not delivered on the planned schedule, it can become a bottle neck in the further production process. The schedule of delivery is after all a precondition for the user of the cargo. The value, suffered from delay, can be considered as the second component of time costs.

Cost Calculation

A complete view of the costs emerging along the total transportation chain can not be made if not all costs are represented. Not only the time-related costs need to be taken into account, also the general transportation costs per transport module, fixed as well as variable, should be included. Therefore it is compulsory to have a detailed overview of all the costs made the different transport modules. When some costs, time based of non-time based, of a certain modality or process are ignored or forgotten, the drawn conclusions might have a larger margin of error than expected. By that the degree of truthfulness is reduced and the conclusions are less useful.

From the literature an overview of all the concerned costs is available. This is used for cost-benefit analysis and provides an analytical framework for comparing the consequences of alternative situations. Nine cost blocks can be examined according to Recordit.

[1] RECORDIT (REal COst Reduction of Door-to-door Intermodal Transport) is an organisation which has the objective to improve the competitiveness of inter-modal freight transport through the reduction of cost and price barriers which currently hinder its development, while respecting the principle of sustainable mobility [27]

1	Personnel	5	Insurances/Taxes/Charges
2	Fixed Assets/ Maintenance of assets	6	Energy and other consumption materials/telephone
3	Stock Turn	7	Time
4	Organisation	8	External Costs
		9	Costs with an internal and external part

On the next page the precise interpretation of these cost blocks is given.

In the cost blocks as given above and in the annex, the costs made by all actors are included. This gives the opportunity to measure the impact of a transport alternative for the entire surrounding community. Use of this method shows whether a transportation alternative will be broadly based.

In the approach from RECORDIT knowledge of specific parameters and figures is required in order to determine the mutually competitive position of the transportation chains from Yangshan and Shanghai.

Cost blocks by recordit

The nine cost blocks as developed by RECORDIT are: Personnel, Stock Turn, Energy and other consumption materials and telecommunication, Fixed assets / Maintenance of assets, Organisation costs, Insurance, taxes and charges, Time, Costs with external and internal parts, External Costs. The specific aspects per cost block are given below.

Personnel	
	Gross wage / salary of driver
	Gross wage / salary of worker
	Expenses incurred by the driver
	Social security
	Overhead
	Administration
	Profit / Opportunity
	Advertising, Public Relation
	Advocating / Consulting

Stock Turn	
	Loading / Unloading
	Transhipment
	Shunting, marshalling, rearrangement
	Storage of goods

Energy and other consumption materials and telecommunication	
	Fuel, diesel
	Electricity
	Tyres
	Oil, fat, additional variable cost
	Telephone, telecommunication, radio

Fixed assets / Maintenance of assets	
	Container investment: depreciation and interest
	Container maintenance
	Container repair

	Means of transport - investment: depreciation and interest
	Means of transport - maintenance
	Means of transport - repair
	Technical asset - investment: depreciation and interest
	Technical asset - maintenance and repair
	Building-investment: depreciation and interest
	Building - maintenance and repair
	Property/ site/development-investment
	Infrastructure - investment, maintenance and repair

Organisation costs	
	Management / Transaction
	Disposition of wagon/vehicle fleet/ additional keeping
	ready of wagons and means of transport
	Disposition of cargo /good-dispatching, conducting
	coordination
	Monitoring
	Safety test
	Operational cost for the network (rail/waterway-signalling, station and network management)

Insurance, taxes and charges	
	Insurance of cargo/good
	Insurance for the risk of the enterprise
	Insurance for the vehicle and loading units
	Third party motor vehicle insurance
	Tax,sales tax
	Vehicle tax
	Duty
	Tolls, road pricing
	Fixed road charges, truck vignette
	Rail track user charges
	Lock charge

Time	
	Waiting time
	Rest time for the driver
	Parking, port liner terms charge
Costs with external and internal parts	
	Congestion
	Scarcity, Slot allocation
	Specific road bottleneck, go round
External Costs	
	Accident
	Air Pollution
	Climate Change
	Water Polution
	Noise nuisance

XI Major Ports along the Yangtze

There are 16 major ports downstream of Wuhan in the study area, and apart from the large main port – Shanghai Port, 7 are in Jiangsu Province, 5 in Anhui Province, 2 in Hubei Province and 1 in Jiangxi Province. Characteristics of 1995 of these 16 major ports along the Yangtze river are given in the table below.

Port	Berths			Warehouse	CY
	total	10.000 ton	for	10.000 m2	10.000 m2
Shanghai	140	68	11	34.08	176.40
Nantong	39	7	2	2.55	29.53
Zhangjiagang	13	10	2	3.73	22.94
Jiangyin	11	1	0	0.73	8.49
Gaogang	15	1	0	0.78	2.66
Yangzhou	5	2	0	0.32	3.60
Zhenjiang	94	8	1	4.97	40.80
Nanjing	100	15	2	6.83	66.24
Ma'anshan	23	0	0	0.13	25.01
Wuhu	53	5*	2**	4.17	9.89
Tongling	32	1*	1**	0.60	1.5
Chizou	17	0	0	0	1.5
Anqing	43	2*	0	1.31	6.47
Jiujiang	56	2*	1**	1.49	5.63
Huangshi	49	5*	0	1.07	7.08
Wuhan	117	11*	2	7.10	77.46

* refers to the number of 5000-ton level sea vessel berth
** refers to multi-functional berths

From these ports the Masterplan Study report [29] determined central ports based on the regional importance and potential. These central ports for the Yangtze River Area are: Wuhan, Jiujiang, Wuhu, Nanjing, Zhangjiagang, Nantong and Shanghai.

XII. Calculation Throughput of Nanjing

The calculation of the throughput of the port of Nanjing is based on the expected flow of containers over the Yangtze River. The prognoses of the Masterplan Study Report [29] are used to derive the percentages of containers with destination Nanjing and Ports more upstream. In the Table below these percentages are given for the period 2005 to 2020.

Year	Nanjing	Ports upstream	Total
2005	29.8	20.1	49.9
2007	31.1	21.0	52.1
2010	32.3	22.0	54.3
2015	33.7	23.0	56.7
2020	35.0	24.0	59.0

Table 6

With these figures the actual container volume for the port can be determined as the total volume transported over the Yangtze River is known. When these values are added up the total container volume transported over the Yangtze river from Shanghai Port and Yangshan Port with destination Nanjing is derived.

Year	Total Yangtze Transport (mTEU)	Nanjing TEU	Ports upstream TEU	Total mTEU
2005	2.066	615,668	415,266	1.031
2007	2.075	645,325	435,750	1.081
2010	2.234	721,582	491,480	1.213
2015	2.555	861,035	587,650	1.449
2020	2.996	1,048,600	719,040	1.768

Table 7

As the contribution in container transport is not equal for Shanghai and Nanjing the prognoses for the division are applied to the total volume containers with destination Nanjing. This gives the actual container volumes that has to be transported between Shanghai, Yangshan and Nanjing.

Year	Shanghai (%)	Yangshan (%)	Total mTEU	Shanghai TEU	Yangshan TEU
2005	95.2	4.8	1.031	981,449	49,485
2007	85.5	14.5	1.081	924,319	156,756
2010	70.9	29.1	1.213	860,061	353,001
2015	56.9	43.1	1.449	824,302	624,383
2020	43.3	56.7	1.768	765,388	1,002,252

Table 8

From the table above can be seen that for example in 2007 of the 1.081mTEU destined for Nanjing 924,319 TEU is transported between Nanjing and Shanghai and 156,756 TEU is transported between Yangshan and Nanjing.

Transport from Shanghai and Nanjing are not the only throughput generators for Nanjing Port. Beside the fact that Nanjing port is also called at by Short sea vessels the transport between Nanjing and the ports more upstream is also a throughput generator. From Table 2 can be seen how many TEU are transported between the ports upstream and Nanjing. These should be added to the throughput as they will be transhipped at Nanjing.

Year	Shanghai TEU	Yangshan TEU	Short Sea TEU	Domestic TEU	Total Throughput TEU
2005	981,450	49,490	170,500	415,266	1,616,700
2007	924,320	156,760	193,500	435,750	1,710,325
2010	860,060	353,000	228,000	491,480	1,932,542
2015	824,300	624,380	285,500	587,650	2,321, 835
2020	765,390	1,002,250	343,000	719,040	2,829,680

Table 9

In Table 4 the total expected throughput of Nanjing is given. In 2005 this is 1.62 mTEU, in 2020 this is expected to be increased to 2.83 mTEU.

V. XIII Vessel Dimensions

The dimensions for the used design vessels are given in the table below. These dimensions are obtained from Hansa, may 2003 [47].

Typ of vessel	(-)	WT 164a	WT 168a	WT 170	700TEU	1150TEU	No name
Length over All	(m)	158.1	134.44	178.57	132.3	155.6	132.6
Width	(m)	21.75	22.5	27.6	19.4	24.5	19.2
Draught	(m)	8.91	8.71	10.87	7.37	9.5	7.0
Total Containers	TEU	969	862	1683	700	1,150	681

VI. XIV Tide at the River mouth

The following facts for the Yangtze River mouth are available

MHWS	=	4.1 above CD
MHWN	=	3.0 above CD
MLWN	=	1.6 above CD
MLWS	=	0.5 above CD

According to the figures above the mean value is 2.3 m above CD
When is assumed that MHW is exactly between MHWS and MHWN it can be said that MHW = 3.55 m.
The same can be done for MLW. When is assumed that MLW is exactly between MLWN and MLWS it can be said that MLW is 1.05 below CD.

When the tide is approached as a sinus the equation for the tide movement can be determined:

$$X = 1.25\sin(\frac{2}{745}pt) + 2.3$$

With MHW being 3.55 m and the mean value 2.3m the amplitude is 1.25. The period is derived from the tide being semi-diurnal 12 hours and 25 min which is 745 minutes. 2.3 is the mean value of the water level.

With this approach of the tide an indication can be given for the time the tide brings the water level above a certain level. It must be said that it is a rough indication as a tide is not an exact sinus and also the location is of importance as the tide wave is moving into the river mouth.

XV Calculation of the number of calls at Nanjing

In this appendix the calculations are given from which the number of calls at the port of Nanjing is determined. As four sorts of waterway transport call at Nanjing these are treated separately in this appendix. The container volume figures are derived in the appendix about throughput calculation of Nanjing.

Shanghai

For all years in the prognoses the import and export rate of 48% versus 52% is applied. In the table below the results are given. As the export is exceeding the import the export is determining in the calculations of the number of calls per week as ALL containers need to be transported.

Year	Shanghai TEU	Export TEU	Import TEU
2005	981,449	510,353	471,096
2007	924,320	480,646	443,674
2010	860,060	447,231	412,829
2015	824,300	428,636	395,664
2020	765,390	398,003	367,387

Table 10

With the port being operational 51 weeks per year and 24 hours a day and the assumption that transport is equally spread over the year the total containers to be transported per operational week can be determined. After determination of the normative vessel the number of calls can be calculated. For transport between Nanjing and Shanghai a vessel of 969 TEU is used.

An example for 2005 is given:
With 510,353 TEU exported containers per year and 51 operational weeks, every week 10,007 TEU is exported. With a 969 TEU vessel 10,007/969 = 10.3 calls are necessary. This results in 11 calls per week as can also be seen from the table below.

Year	Calls/wk no.	TEU/trip	% of Ship capacity
2005	11	1,750	90
2007	10	1,813	94
2010	10	1,686	87
2015	9	1,796	93
2020	9	1,668	86

Table 11

In this way the number of weekly calls for all years in the prognoses can be determined. The TEU transported per trip is not equal to twice the capacity of the ship. This is due to the imbalance between export and import and also to not fully using the available slots. The average number of TEU transported per turn around trip can be derived from the weekly transported containers divided by the number of trips. The latter is equal to the number of calls.

For example
In 2005 981,449 TEU needs transport. Per operational week this is (981,449/51) 19,244 TEU. With 11 calls per week the average number of TEUs per trip is 1750. With a vessel capacity of 969 this gives an occupation rate of 1750/(2*969)

The calculation is for all years in the prognoses equal.

Yangshan

Like the calculation for liner services from Shanghai to Nanjing also here first the export and import figures are calculated with a ratio of 0.48 to 0.52.

Year	Yangshan TEU	Export TEU	Import TEU
2005	49,490	25,735	23,755
2007	156,760	81,515	75,245
2010	353,000	183,560	169,440
2015	624,380	324,678	299,702
2020	1,002,250	521,170	481,080

Table 12

With vessel coming from Yangshan passing the river mouth the same calculation as above are made but now for two design vessels based on the two dredging phases. The determination of the preferred situation is found in chapter 9.

Year	Dredging phase	Design Vessel TEU	Calls/wk no.	TEU/trip	% of slot capacity
2005	phase 1	700	1	970	69
	phase 2	969	1	970	50
2007	phase 1	700	3	1024	73
	phase 2	969	2	1537	79
2010	phase 1	700	6	1154	82
	phase 2	969	4	1730	89
2015	phase 1	700	10	1224	87
	phase 2	969	7	1749	90
2020	phase 1	700	15	1310	94
	phase 2	969	11	1787	92

Table 13

In the table above the chosen vessels and the accompanying figures are marked.

Short-sea

Also Short-sea vessels calling at Nanjing have to pass the river mouth. Therefore the process for these vessels is equal to the vessels coming from and going to Yangshan. The calculations of Shanghai are also valid for short-sea transports

Year	Short Sea TEU	Export TEU	Import TEU
2005	170,500	88,660	81,840
2007	193,500	100,620	92,880
2010	228,000	118,560	109,440
2015	285,500	148,460	137,040
2020	343,000	178,360	164,640

Table 14

In the table on the next page again the chosen options are marked.

Year	Dredging phase	Design Vessel TEU	Calls/wk no.	TEU/trip	% of slot capacity
2005	phase 1	700	3	1114	80
	phase 2	969	2	1672	86
2007	phase 1	700	3	1265	90
	phase 2	969	3	1265	65
2010	phase 1	700	4	1118	80
	phase 2	969	3	1490	77
2015	phase 1	700	5	1120	80
	phase 2	969	3	1866	96
2020	phase 1	700	5	1345	96
	phase 2	969	4	1681	87

Table 15

Ports upstream of Nanjing

The vessels transporting containers to and from ports upstream of Nanjing are of smaller scale than the other vessels. However, that doesn't change the calculations. Also here the ratio import and export (of 0.48 to 0.52) is applied to the total transported volume.

Year	Domestic TEU	Export TEU	Import TEU
2005	415,266	215,938	199,328
2007	435,750	226,590	209,160
2010	491,480	255,570	235,910
2015	587,650	305,578	282,072
2020	719,040	373,901	345,139

Table 16

With vessels of 108 TEU the number of calls, the average number of TEU per trip and the occupation rate of the ship capacity can be determined.

Year	Calls/wk no.	TEU/trip	% of Ship capacity
2005	40	204	94
2007	42	204	94
2010	47	205	95
2015	56	206	95
2020	68	207	96

Table 17