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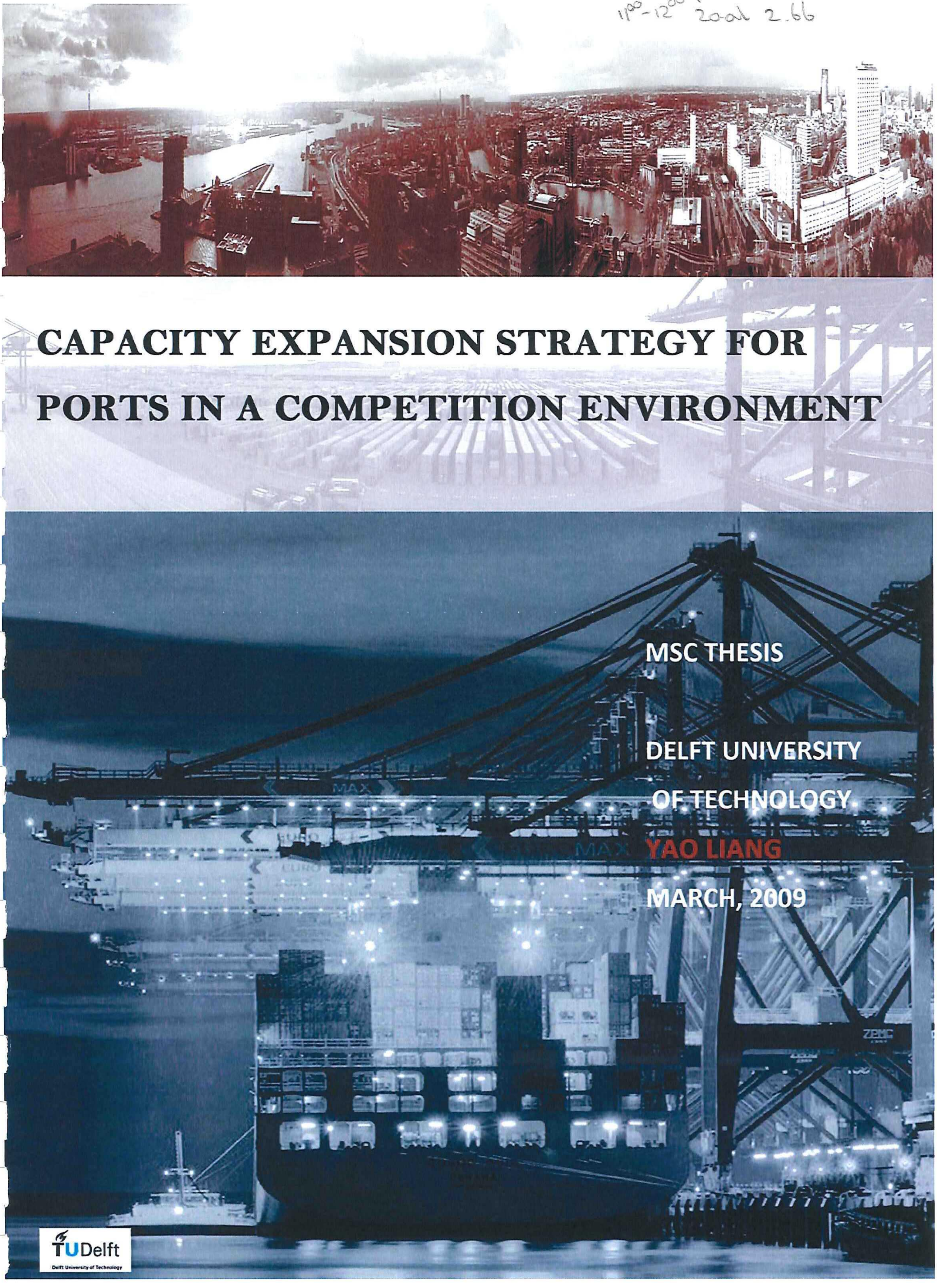

CAPACITY EXPANSION STRATEGY FOR PORTS IN A COMPETITION ENVIRONMENT

MSC THESIS

DELFT UNIVERSITY OF TECHNOLOGY

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Capacity Expansion Strategy for Ports in a Competition Environment

MSC Thesis

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Colophon

Msc Thesis:	Capacity Expansion Strategy for Ports in a Competition Environment
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Preface

This report is the final result of the master thesis project undertaken by Yao LIANG, a student majoring in Transport, Infrastructure & Logistics (TIL) which is a two-year Master of Science, jointly operated by three faculties: Faculty of Civil Engineering, Faculty of Mechanical, Material & Maritime, and Faculty of Technology, Policy & Management at Delft University of Technology.

The aim of this research is to provide information to the port authorities what could be the best strategy to deal with the port capacity expansion problem in a competitive environment by using a model to simulate the effect of hinterland transport, port congestion and port investment. It has been an over-six-month life journey with twists and turns for my master thesis. I am indebted to everyone who has ever contributed to and helped me during these several months.

First of all, I would like to acknowledge the crucial contributions of Prof. Ir. F.M. Sanders, providing me with this challenging thesis subject that I have been looking for and support my research with admirable motivation. I would also like to especially express my gratitude to Dr. Ir. R.J. Verhaeghe and Drs. J.C. van Ham who gave me sufficient advices and supports during the many discussions and meetings.

Furthermore, I would like to acknowledge Ir. Marcel W. Ludema for his help in the coordination issues concerning my study and graduation. And I am also grateful to all the people who ever give lectures or advice to me during my study at TU Delft, who provides me with the knowledge and foundation to complete this thesis.

Finally I would like to thank my family and my friends for their support during my master study at TU Delft, especially during the last six months of my master thesis project. They contributed to my two and half year's life journey in many more ways than they realize. To all of them I give my gratitude.

Specially, I dedicate this thesis to my grandfather. He died on Tuesday, 13th Jan, 2009. It is that combination of high integrity and simple humanity that made him not just respected but loved by me. If the heaven exists, he has gone there.

Yao LIANG

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March, 2009

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Summary

This thesis carries out the capacity expansion strategy for port in a competition environment. A new model which deals sea port as a node in the logistic chain will be built in this study. And the port of Rotterdam and port of Antwerp will be used as a special case study.

Nowadays containers are widely used in world trade business. Millions of containers are being moved from one point to another every single day. In the last decades, world container traffic has increased enormously because of the increasing world population and the more specific needs of customers. The world container traffic increased from around 100 Million TEU in 1990 to around 400 Million TEU in 2005 (Hofstra University). And the container traffic is expected to remain growing in the future. The growth in international container shipping will continue with the expected percentage of 9% annually up to 2015 (Heymann, 2006).

Ports, as facilities for accommodate ships and transferring cargoes, play essential nodes in maritime-land freight transport network. The strong growth in container industry, gives a good opportunity for port development on one hand. On the other hand, ports are facing great pressure of handling with the rapid-growing container traffic. Due to the enormous growth in total demand and uncertain demand fluctuation in short periods, ports are always faced with capacity problems, either short-capacity or over-capacity. When taking into account new trends in containerization, and intensively increasing competition among ports in regional port clusters, port planning in capacity will become even more significant. Therefore, developing best strategies to deal with port capacity expansion problems in competitive environments is a main challenge faced by port authorities.

In order to provide information to port authorities when they make port capacity expansion strategies, simulation models are widely used. In these simulation models, main focus is on hinterland transport network, because of the quality of hinterland transport has become increasingly important for the competitiveness of a seaport (Konings, 2007). Basically, two types of approaches for transport modeling can be used in transportation planning concerning port capacity problems. One is simulation of route assignment in network, e.g. the SMILE model (Strategic Model for Integrated Logistics and Evaluation) developed by the Dutch institute TNO, which simulates the assignment of freight flows for different commodity types and transportation modes. The other one is projection of port demand based on macro-economic relationships with a more or less fixed market share for a particular port. The example of this second approach is the GSM model (Goederen Stromen Model) used by the Port of Rotterdam. But there are some limitations in these two approaches. The first approach does not account for port development. This approach mainly focuses on hinterland transportation network. However, port investment characteristics are not taken into account in this approach. The second

approach accounts for port development, but does not incorporate the potential changes in a port's market share caused by, for instance, competition between transportation routes or port service level. In this case, it is essential to develop a new model, which combine these two fore-mentioned approaches, with the capability of both simulating the effect of competition and incorporating autonomous demand growth.

In this thesis, a new concept is formulated that sea port is considered as a node in total logistic chain. A new dynamic port planning model is developed with Microsoft Excel Program. In this port planning model, factors of port capacity, port-commercial and public interests, port competition, capacity problems of hinterland infrastructures are all taken into consideration.

An actor analysis is firstly carried out in the thesis. The main actors in container industry are analyzed, including terminal operators, port authorities, shipping companies, inland transport operators, manufacturers and consignees. Market share, port utilization, traffic volume, and unit cost are concluded as the main interests of port authorities.

Based on the conclusions of actor analysis, the port planning model is developed with three key inputs, including (1) port residence cost and congestion; (2) port investment cost; (3) hinterland transport cost and congestion.

This model is developed based on the following iterative mechanism: In one year, these three aspects (i.e. port residence cost, port investment cost, and hinterland transport cost) determine the unit transshipment cost per TEU of this same year and ultimately determine ports' market share of the same year. However, the market share of this year would determine the three costs of the next following year (i.e. port residence cost, port investment cost, and hinterland transport cost).

In the iterative process, several other factors are also included. Port capacity also affects the port residence cost of the same year. The new capacity added is another factor that affects the port investment costs of the same year. Hinterland infrastructure also affects the hinterland transport cost of the same year.

A case study is carried out by means of the port-planning model. In this case study, port of Antwerp and port of Rotterdam are chosen as the two competition ports. Time horizon of 30 years is analyzed with thirty iterations.

First of all, a general description of both ports is shown, including geographical location, historical overview, port statistics, hinterland connection, future expansion planning and containerization in each port. Based on this basic port information, five scenarios and assumptions are made as follows: changing expansion plans; changes in port congestion; changes in hinterland congestion; global economy development; combination of strategies with uncertainty. The first two scenarios (changing expansion plans and changes in port congestion) can be fully determined by port authorities. But for the third (changes in

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hinterland congestion) and fourth (global economy development) scenarios, port authorities have very limited power on it. Therefore, uncertainty with strategies, as the fifth scenario, is also analyzed by simulation.

From the simulation results of these five scenarios, the following conclusions are derived in this thesis:

1. A new concept which trade sea port as a node in the logistic chain is implemented in this thesis.

2. A new model is made in this thesis. Compared with the existing transport model (SMILE & GSM), the model made in this study is not only containing the hinterland transport network, but also taking port development and the changes in market share into account.

3. The inputs of the model are the factors which influence port competition and the outputs of the model are the key elements that the port authorities interested in.

4. A combination strategy can be simulated to find the interaction of the uncertainties in the future.

At the end of the thesis, limitations of the research and recommendations for further research are discussed. The main limitations in this thesis include both research limitation and model limitation. In this study, the competition is restricted to inter-port competition and only in container market. In the model, merely thirty percent of the total throughput is taken into account. And the cost of transportation, port congestion and port investment are calculated in a rough level.

And for further study, main focus should be on modeling at a disaggregate level, in which way more accurate results can be derived. And a thorough analysis on port congestion, port investment recovery is better to consider. And other alternative methods to ease competition problems are also need to be taken into account.

To sum up, the concept used in this thesis and the model developed in this study are useful to analyze port capacity expansion strategy. It can provide information to port authorities to choose the best strategies to deal with port capacity expansion problems in competitive environments by using the simulation model. Effects of hinterland transport, port congestion and port investment can be effectively shown in the simulation result. Also, the model can be easily expanded for dealing with more complex issues.

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1 General introduction

In the chapter, a general introduction will be given. Firstly, a general background will be given. Then the main issues of port capacity and port competition will be analyzed. Based on these, the problem will be formulated. Finally, the study scope, the research objective and research question will be set.

1.1 Introduction

In the last decades, with the development of globalization, world-wide trade became more and more important. The international mobility of goods and service became a key issue in recent years. This kind of mobility is mainly accomplished by sea transport. Ports, as an essential node in maritime-land freight transport network, have to make strategic decisions in the face of a strongly growing market and volatile demand.

In regional port cluster, the competition among ports is increasing intensively. For example, in Europe, several ranges can be distinguished: the Atlantic, the Irish-British, Scandinavian, Baltic, Mediterranean and the Hamburg-Le Havre range. Four of five biggest European sea ports are situated in the Hamburg-Le Havre range: Rotterdam, Antwerp, Bremen and Hamburg. So, these ports are in intensive competition for vessels' calling at port and shippers' cargo. The highly intensive competition tends to result in the loss of all competing ports. Faced to this problem, the port authorities are looking for a new approach to achieve the cost savings and rationalization in port expansion. They seek a better strategy to realize the optimization with their competitors.

Currently, the port competition puts pressure on cost recovery and pricing influencing the attractiveness of the port, determining its market share, and in turn the viability of investments. It has forced port authorities to compete in many different areas. One of the very basic areas is the port capacity. The capacity is considered as the most important competitive priorities. As it is the key issue to determine the port service level, such as the service time and the service price.

At the same time, the quality of hinterland transport has become increasingly important for the competitiveness of a seaport. Shippers and carriers value the attractiveness of a port on not only the performance of the seaport, but also on its hinterland accessibility (Konings, 2007). This holds for the container transport market in particular. Containerization has changed liner shipping spectacularly and affected seaports and their hinterland transport systems.

As a result of this, the investment decision making has to incorporate many factors, such as scale effects, congestions, competition, hinterland transport, and a financing and pricing. Port competition strategy is attracted many attentions in both academic and practice. Several methods are used to solve this problem. One method is called simulation. By making models to simulate the future development, the influence of the strategies which are made by the port authorities will be analyzed. And then several suggestions will be given to find the best strategies.

In the previous studies, several models made which are focusing on the two main factors which mentioned above, separately. For example, a model made by Dekker, is used to simulate the port capacity expansion strategy. In these kinds of model, only the port development, such as port capacity, total volume, and utilization and so on are taken into account. On the other hand, several freight transport models are made to simulate the transportation network, such as SMILE model (Strategic Model for Integrated Logistics and Evaluation) developed by TNO and GSM model (Goederen Stromen Model) used by the Port of Rotterdam. In these two models, main attentions have been put on the hinterland transport, such as modal split, travel distance, and travel cost. The main limitation of these models is that, the port development and the market share changes are not accounting.

Based on the factor mentioned above, a new model will be built and used to simulate the port expansion strategies for ports in the competition environment in this study. A combination of both approaches port development and transport network can be used to simulate the effect of competition and to incorporate autonomous demand growth.

In the following section, more general introduction of port capacity and structure of the thesis will be further analyzed.

1.2 Port capacity

In this section, port capacity will be introduced. Section 1.2.1 will be defined port capacity. In section 1.2.2, capacity problem will be given. And in 1.2.3, the capacity planning and capacity management will be set. Finally, in section 1.2.4, there will be a short discuss on ways to solve the port capacity problem.

1.2.1 Definition

Capacity is an essential issue of the infrastructures. It means the capability of the infrastructure to provide a particular service. Changes in capacity can directly influence the service level of the infrastructure, which is normally measured by service time and service cost. According to Manheim, capacity can be defined as the maximum number of items that can be 'squeezed' through a system or its components per unit of time.

Port capacity is the combination product of port facilities, such as land, infrastructure, superstructure, and maritime and hinterland access infrastructure and associated services, which mainly mean cargo handling services. In this thesis, the container port capacity will be measured by the number of containers that can be handled per year.

The effective capacity is determined by the following characteristics (Manheim, 1984):

- Design variables such as numbers, sizes and surface areas,
- Quality and reliability of services determined by labor, applied technologies, and service schedules, quality of management;
- Nature of the demand such as arrival rates and the handling characteristics of the transported items, and
- Environmental factors such as the function of the surrounding area and weather conditions.

1.2.2 Capacity problem

Capacity is a significant characteristic for the port. Facing to the strongly growing market and the volatile demand, the port capacity needs to strike a balance between the demand

and supply. Generally speaking, there are two kinds of capacity problem that occurs as a result of the dynamics of competition, one is the shortages in capacity and another one is over-capacity.

A shortage in capacity means that the demand of the market is more then supply. It will decrease the service levels in several ways, such as the highly price, the increasing in port congestion and the associated delay for port users. It leads the port in a worse competition position. In competition environment, the port users will be attracted by the other cheaper and less congested port in the same regions. So, the market share of these ports which is shortage in capacity will be reduced.

Over-capacity means the port offers too much supply then the demand of the port market. A port with over-capacity is more attractive for potential users due to its low level of congestion. But at the same time, it also means low utilization ratios and the difficulties in investment recovery. A growing demand combined with economies of scale in investment cost lead to an expansion strategy with substantial capacity increases; over-capacity is then a time-varying phenomenon.

Considering the port competitiveness, a certain amount of over-capacity is required. Otherwise, in the short term, port demand may fluctuate causing temporary shortages in capacity due to peak loads. So, the extra capacity is needed, but the utilization ratio is also an important factor that need to be take into account when the port authorities making the port capacity planning.

1.2.3 Capacity planning and capacity management

To deal with the capacity problem, the capacity planning and capacity management will be used.

Several definitions of capacity planning and capacity management can be found in the literature. Manascé (1999), for instance, defined capacity planning as the process of predicting when adequate service levels will be violated as well as determination of the most cost-effective way of delaying system saturation. Capacity management can be defined as the set of decisions that results in a certain capacity including the rules that are used to implement capacity.

In this thesis, the capacity planning will be defined as the same as technical-economic analysis of matching supply of capacity with the demand for services, and engineering of alternative options to improve that match (Dekker, 2005). And a distinction should be made between operational planning and strategic planning. The operational planning which emphasizes that the infrastructure operator should do to deal with short-run (e.g. daily) demand fluctuations for a given capacity. And the strategic planning emphasizes longer term provision of infrastructure services. The capacity planning of this thesis is mainly strategic planning, which is more focus on the long term capacity expansion.

Capacity management will then be defined as the managerial response to capacity problems (shortages in capacity and over-capacity). Capacity management decisions are the basis of the outcome of capacity planning. Such decisions can be complex due to, for instance, the difficulty in determining an acceptable level of congestion (Dekker, 2005), the uncertainty of future demands.

1.2.4 Ways to solve the port capacity problem

There are several ways to deal with the inner port capacity problem, which includes:
- More crane/container drawer;
- Increase utilization rate;
- Land reclamation;
- Better terminal design;
- Spreading of activities;
- Reallocation of activities; and
- Capacity expansion

Some of the solutions are face to short terms, such as more crane/container drawer and increasing utilization rate. Others are focus on the long terms, such as capacity expansion. In this thesis, the main attention will be put on the capacity expansion. So, the output of this report will be suited for the long term development of the port.

A complex capacity planning case may include: scale effects, congestion effects, uncertainty, network effects, competition, and pricing and so on. Especially, for port capacity planning in a competition environment, the following aspects need to be taken into account:

- Potential growth in demand depends on the overall (world-wide) growth in containerized cargo.
- Shifts in the relative flows over the O-D network can be expected based on the relative developments in different hinterland regions
- The demand will be strongly influenced by competition which depends on the choices will be made between the many logistic chains which are possible to service to different O-D pairs. Changes in port services (pricing) will influence competition. Potential changes in transport technology (e.g. bigger ships) and changes in hinterland routes and modes of transport will also influence demand.
- Uncertainty is associated with projection of the overall transport volume and the share handled by each port which will be influenced by uncertain developments in hinterland locations, developments in transport technologies and transport routes

1.3 Port competition

In general, port competition can be categorized into six categories (Robinson, 2002) comprising competition between:
- Port ranges or coast lines;
- Ports in different countries;
- Individual ports in the same country;
- Operators or providers of facilities within the same port;
- Different modes of transport; and
- Supply chains.

In this thesis, the main point of view is the last category, the supply chains. The port authorities will pay great attention on the transport-logistic chains, to make their own port get a higher market share in regional port competition environment.

Port, as a node in the elaborate logistic network connecting origins and destinations for maritime freight flows is showed in the Figure 1-1. The market share of the port is essentially based on the service level of the total logistical chain. In the past, the freight transportation would choose the geographically closest port as a node. But in recent years, the shipper changes to the port with low price and low congestion in the same regions. So, for port authorities, they should constantly be on the alert for potential route shifts. When they make the port capacity expansion strategies, they must take into account the possibilities of the port offers for the entire transport-logistic chain, including intermodal facilities and adequate hinterland connections.

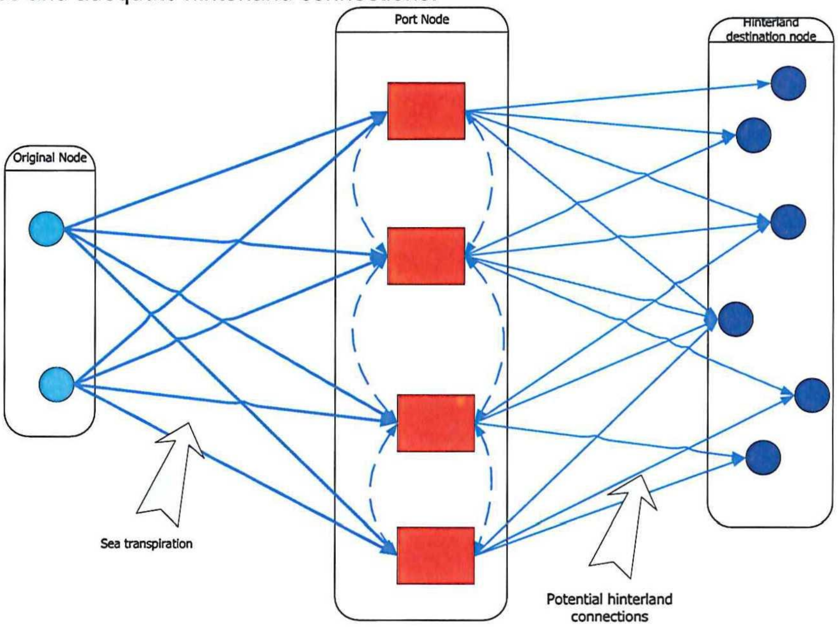

Figure 1-1 Schematization of the maritime-land freight transport network

Many routes can be used for transporting goods. For example, a container needs to be transported between shanghai in China and the Ruhr Basin in Germany (Seeing figure 1-2). The shipper can choose the route via port of Rotterdam, which use more maritime transportation but less land transportation. So, the transportation cost is low, but it may take a longer time to the destination area. The shipper could also choose the route though port of Marseille, which is shorter and faster. But the total cost is much higher. These cost and time patterns become even more complex by the service times and durations experienced in the ports.

Figure 1-2 Route choice from Shanghai in China to Ruhr Basin in Germany

So, several trade-offs will be made by the shippers when they make the route selection decisions. In the case that all the freight carriers have the full information on the potential port between the original areas and the destination areas, the service level of the port will determine its competition position. So, the port authorities could use different competition strategies to make port more rivalrous, even the shipping lines usually offer a multi-port service in a specific port range.

1.4 Problem analysis

From the analysis above, it is can seen that how to improve the port competitiveness is the main issue for the port authorities. Physical expansion of port capacity is a good strategy for long term development. Because of the capacity expansion can leads to a reduction in port-congestion costs, as a result it can make the port more attractive for liners. And it also allows autonomous growth of port demand.

The port capacity expansion is considering as the essentially decision-making on port investment. And to make the decision robust, the following six questions need to be taken into account (Dekker, 2005):

- What is the demand for services in terms of types and volumes of the transport flows;
- What is the supply of capacity in terms of physical characteristics (sizes and numbers) and service characteristics (tariffs and productivities);
- What is the utilization rate and equilibrium demand;
- What are the costs and the price;
- What are the economic benefits; and
- What is the overall viability of the port investment project.

At the same time, Container shipping has enabled new kinds of liner service networks such as the hub-and-spoke formation, putting pressure on the performance of hub ports and the feeder networks to these ports over sea and land. McCalla (1999) and Haezendonck and Notteboom (2002) argue that containerization has increased the geographical market coverage of seaports to the extent that the concept of a captive hinterland is no longer valid. Fewer ports are much more in competition to serve the same inland areas. Especially in Northwest Europe, where the distance of container ports to major cargo generating inland areas is not a very distinguishing factor, this has made hinterland accessibility a strategic matter.

These components are included in a flow diagram for planning of port capacity under competition as presented in Figure 1-3.

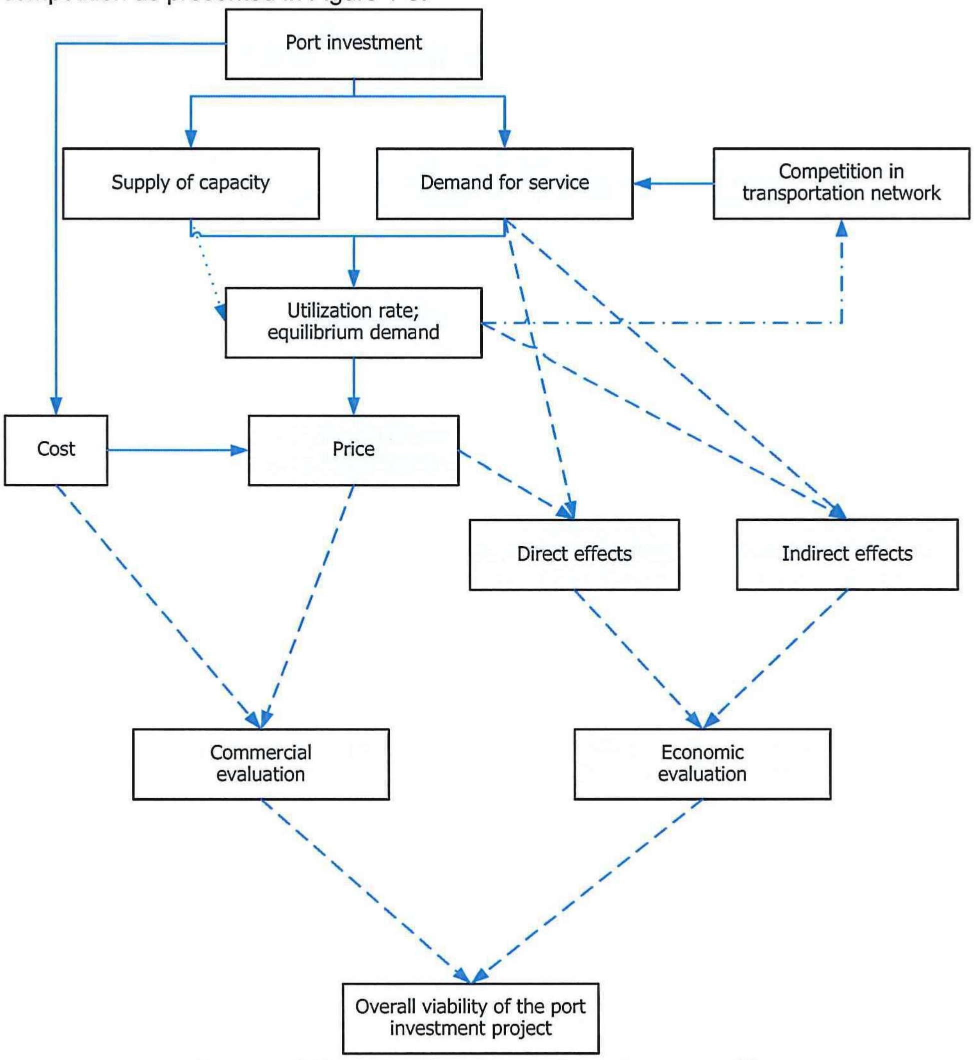

Figure 1-3 Planning of port capacity under competition

From figure 1-3, it can be found that the planning of port capacity is a complex issue. When the decision is made , a lot of factors need to be considering. And in the competition environment, the situation could be more intricacy. Not only the capacity of own port, but also the influence of other ports in the same region need to be take into account. So, how to manage the port capacity expansion in competition is an essential issue for port authorities, especially for those ports in the same areas.

1.5 Study scope

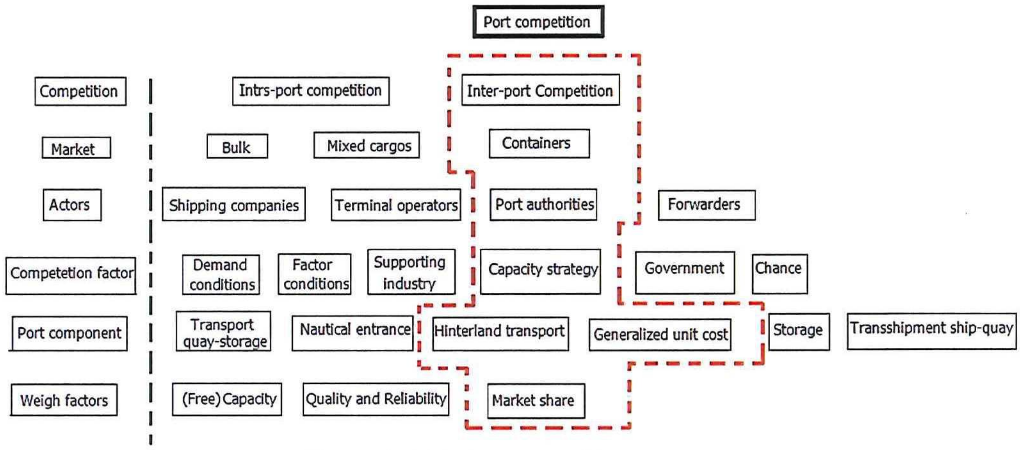

Figure 1-4 Study scope of thesis

In the figure 1-4, the study scope of this thesis is defined.
In the competition areas, this thesis focuses on the inter-port competition. That means the competition between different ports. And the competition is in the container market, which is the fastest growth market and it will be the dominant market in the future. No attention will be paid on the bulk and mixed cargos. The main actors in the port competition include shipping companies, terminal operators, port authorities and forwarders. In this thesis, the competition is between the port authorities. And the most significant competition area is the capacity strategy. Some other factors, such as demand conditions, supporting industry and government, will also influence the capacity strategy to a certain extent. The port component will be limited in hinterland transport and the generalized unit cost. Because the main battle fields of the port competition in nowadays is in the hinterland part. Even the port authorities have less power in this area (Federal government is responsible for this), but this factor must be taken into account when making the port planning. And the generalized unit cost will directly influence the choice of the shipping companies, manufactures and consignees. Those two factors influence the port competition dramatically. Last but not least, the market share will be used as weigh factors. Because the higher market share means higher port profit and it is the most important thing for the port authorities.

The table 1-1 shows the different port capacity measure. The focus in this thesis is on the structural measures, in particular hinterland transport and also a non- structural measures, that is congestion pricing.

Table 1-1 Operational and strategic port capacity measures
(Source: Dekker, 2005)

<table>
<tr><th colspan="2"></th><th>Operational measures</th><th>Strategic measures</th></tr>
<tr><td colspan="2" rowspan="6">Structural measures</td><td rowspan="6"></td><td>Dredging works</td></tr>
<tr><td>Removal of obstacles</td></tr>
<tr><td>Application of locks</td></tr>
<tr><td>More crane/container drawer</td></tr>
<tr><td>Additional road and rail connections</td></tr>
<tr><td>Land reclamation</td></tr>
<tr><td rowspan="11">Non- structural measures</td><td rowspan="9">Supply management</td><td rowspan="9">Improved berth capacity
Improved yard capacity
Improved gate capacity</td><td>Exchange of information</td></tr>
<tr><td>Loading/unloading without berth</td></tr>
<tr><td>Interference</td></tr>
<tr><td>Better terminal design</td></tr>
<tr><td>Improved port-land interface</td></tr>
<tr><td>Spreading of activities</td></tr>
<tr><td>Reallocation of activities</td></tr>
<tr><td>Privatization</td></tr>
<tr><td>Private funding of investments</td></tr>
<tr><td rowspan="2">Demand management</td><td rowspan="2"></td><td>Congestion pricing</td></tr>
<tr><td>Redirection of cargo flows</td></tr>
</table>

1.6 Research objective

Based on the problem and study scope described above, the objective of this thesis is:

Provide information to the port authorities what could be the best strategy to deal with the port capacity expansion problem in a competitive environment by using a model to simulate the effect of hinterland transport, port congestion and port investment.

1.7 Research question

To achieve the goal stated in the previous paragraph a research question needs to be formulated. This research question has to be answered during this project. The question is:

How can a simulation model be used to provide the best strategy for port authorities to deal with the port capacity expansion problem in a competitive environment?

1.8 Sub-questions

To achieve the research objective, several sub-research questions are summed up below:

1. What is the current situation in Rotterdam and Antwerp?

2. What are the existing port capacity strategy and the limitation of these strategies?
3. What kinds of difficulties occur in port in competition?
4. What is the existing model used for simulating port capacity and hinterland transportation?
5. What is the limitation of the existing model?
6. How to expansion the existing model?
7. The usage of the new model?
8. How to find the best strategy for port authorities of Rotterdam and Antwerp?

1.9 Outline of this thesis

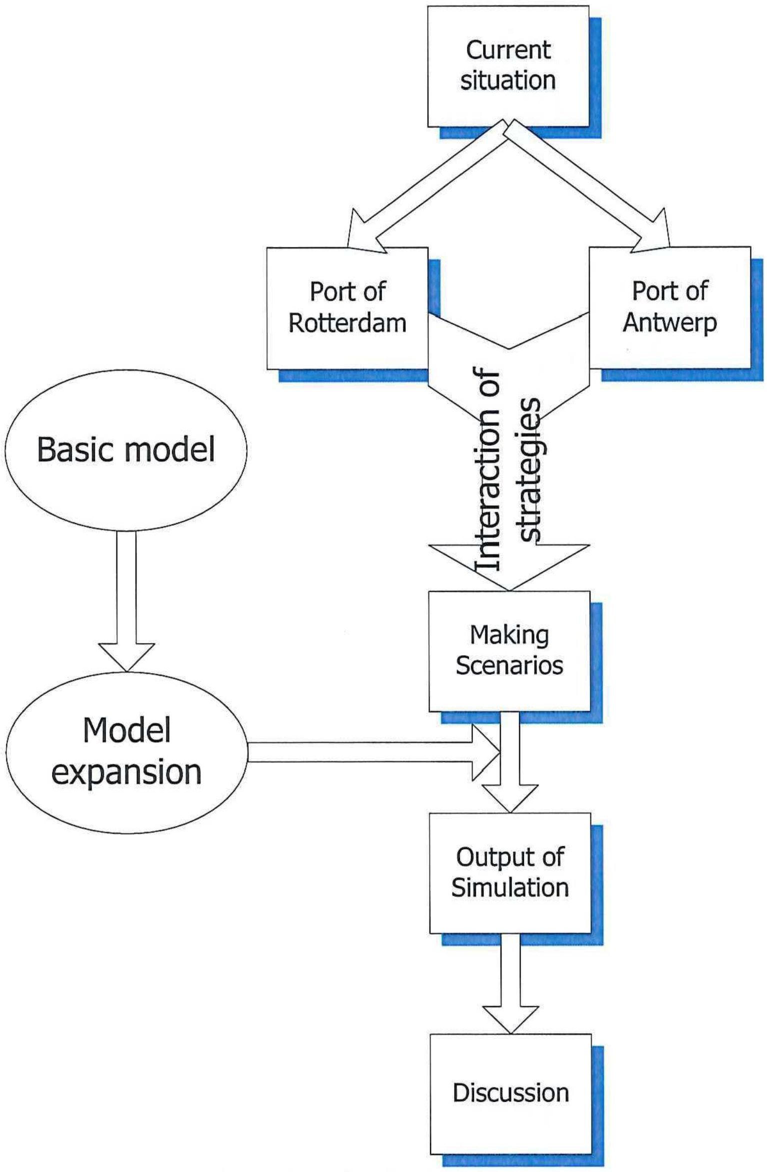

Figure 1-5: The thesis framework

In chapter 2, the current situation will be analyzed.

In chapter 3, the system of dynamic port planning will be described. And the background of the dynamic port planning and the existing approach will be analyzed. Based on this analysis, the limitation of the existing system will be shown.

In chapter 4, there will be a short introduction of the model used in the previous research, including its usage and its limitation. And based on it, a new model will be made.

In chapter 5, the data which need for the model will be set.

In chapter 6, a case study will be given. Firstly, the port of Rotterdam and port of Antwerp will be introduced as the case study. Then, the different scenarios will be given.

In chapter 7, the output of the model will be gathered and analyzed briefly.

In chapter 8, the result will be analyzed to get the conclusion and recommendation.

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2 Current situation

In this chapter, the current situations about the containerization will be introduced in section 2.1. Then, in section 2.2, an insight view of the importance of container ports in the container flow will be given. In section 2.3, the new tendency in shipping and the container terminal industry will be showed. And in section 2.4, it will be a genera actor analysis.

2.1 Containerization

In the middle of 1960's, the standardized maritime container had been introduced in international trade. The usage of container for oversea freight transportation improved the international trade in many aspects. In the past, the goods were usually packed in crates, boxes, nets and other kinds of units, which had a negative effect on safety and transit speed. Since then the use of the standardized maritime container, one of the most advantages was the transfer of goods became much easier, faster and safer. After five decades development, it increased dramatically and it is now the dominate transport unit in continental and intercontinental trade. At the same time, the maritime container is very popular in national land transport, too.

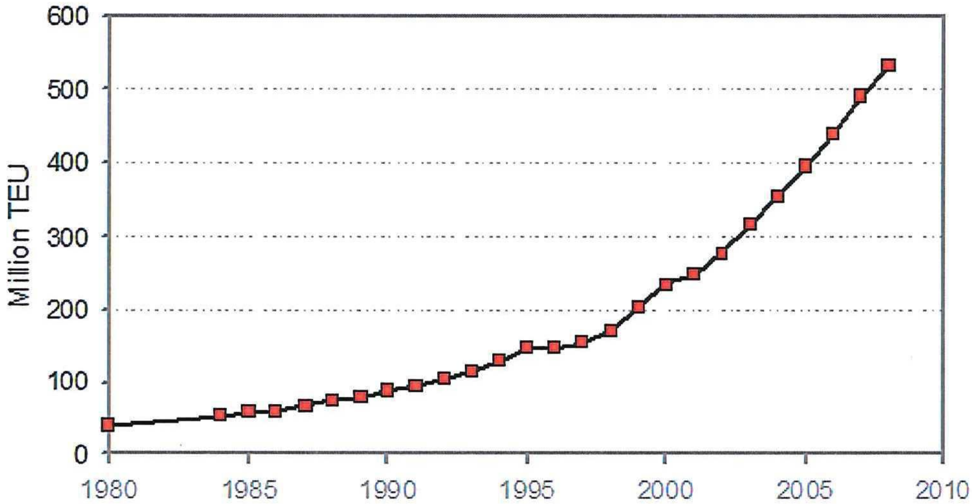
2.1.1 Historical overview

Containers are relatively uniform boxes whose contents do not have to be unpacked at each point of transfer. They have been designed for easy and fast handling of freight. Besides the advantages for the discharge and loading process, the standardization of metal boxes provides many advantages for the customers, as there are protections against weather and pilferage, and improved and simplified scheduling and controlling, resulting in a profitable physical flow of cargo (Dirk Steenken, 2004).

On April 26, 1956, a crane lifted fifty-eight aluminum truck bodies aboard of a tanker ship in Newark, New Jersey, which took aboard the metal boxes to sail them to Houston. After this moment the containerization began (Levinson, 2006). The containers produced a huge reduction in port handling costs, contributing significantly to lower freight charges, and in turn, boosting trade flows. An additional important benefit of containerization is the improved cargo security.

First regular international sea container service should began about 1961 with an international container service between the US East Coast and points in the Caribbean, Central and South America (Dirk Steenken, 2004). At the beginning, the growth of the usage of standard maritime container was very slow. But after large investment in new designed of container ships, an adaptation of suitable equipment in the seaport terminals and availability of containers, a rapidly growing in market share and the economic efficiency were realized in this industry.

At this moment the container is a widely accepted and used item in the world and millions of containers are being moved from one point to another every single day. In the last decades, the use of containers increased enormously. This is because of the increasing world population and the more specific needs of the customers. The figure below shows the World Container Traffic of the last decades.



(Source: Hofstra University)
Figure 2-1 The total number of annual world Container transportation (Millions of TEU)

As can be seen in the figure above the world container traffic has increased enormously in the last decade, from around 100 Million TEU in 1990 to about 400 Million TUE in the 2005.

The reflected line in the figure above gives the impression that the container traffic remains growing. The growth in international container shipping will continue with the expected percentage of 9% annually up to 2015 (Heymann, 2006) But the current international credit-crisis, which is leading the US economy into recession, has predicted further negative impacts for Americans from the U.S. and global financial crisis. Experts expect that the crisis will result in increased poverty and inequality. Liliana Rojas-Suarez, Centre for Global Development, suggests that impacts will be felt in two channels. First, lower growth in the industrial countries will mean less demand for developing countries' exports, both manufactured goods and most commodities. The second channel will be a reduction in capital inflows to developing countries. So, the increasing rate will be less in the coming future.

All these containers need to be stored and transported to all different places in the world. In the next paragraph, the different processes in container supply chain will be described.

2.1.2 General processes in containerization

The most important characteristic of containerized supply chain is the very high grade of standardization. This is the key factor that the containers have been such a great success in the industry. Due to the high grade of standardization, the container can be handled and transported all over the world. Generally speaking, the processes of containerized supply chain are described as follow:

The first step of the containerized supply chain is that, the empty container is needed at the factory. The empty container will be brought from the empty container depot to the manufactory area, where the container is filled with goods.

The empty container depot (see figure 2-2) is used to relieve pressure of the seaport where storage of empty containers is not always possible due to limited storage capacity. At the empty container depot, containers will be stored, repaired or maintained. The main function of these depots is to provide a location where the container can be stored. In another words, the empty container depot is the "warehouse" of the seaport on the dry land. Empty depots are often located near deep sea and inland terminals.

Figure 2-2 Empty container depot of METRANS Group (CZ)

Then, after the container has been filled, it would be brought to the inland container terminal where the containers are collected to be transported to the port. Or, it is also possible that the containers will be brought to the port for the deep sea transportation, directly.

The movement of container between empty container depot, manufactory and sea port will be accomplished by three possible modalities: road, railway and inland waterway. Most of empty container depots are well connected by these three modalities. The shippers or consignees, depending on who is paying for transport, will make a well considered choice in which modality or combination of modalities is best suited. The most important factors in this consideration will be costs, available infrastructure and available time.

The characteristics of modalities:

Road:

Transport by road is characterized by a high grade of door to door service.

In most cases it is possible for trucks to bring the container directly to its destination without any transfers. This means that handling is kept to a minimum thus keeping cost and time waste low. On the other hand fuel prices are rising meaning that price per kilometer are relatively high, over long distances transport by truck will become less attractive. And due to the congestion on the road, the transportation time will be less predicable.

Railway:

Transport by rail has a good interconnection with high capacity and speed, if the direct connection with the destination area is available. Often transport of goods by rail is restricted to railway time table, which means that the waiting times can become long if there is a bad connection. Also train transport on short distances is subject to more handling costs since goods often have to be transported to their final destination by truck.

General commerce and dedicated trains are two types of rail service available. General commerce trains, also named as regular trains, or mix trains, are the majority of rail traffic today. They carry all kinds of goods, and stop at rail yards and siding along the way to add or remove cars. The schedule for a shipment made by regular trains is dependent on the carrier's timetable, which may result in shipment being delayed en route waiting for the next train traveling in its direction. (Moore, 2003)

The dedicated train is a train that carriers only one commodity or loading units such as containers from origin to destination, only stopping to refuel, to change crews, and if more than one carrier is required, to change locomotives. Dedicated trains are usually considered to be a subset of regular trains' service that is characterized by homogeneity of cargo (WIEB 1995, DOT 1998). Due to all the locomotives in the dedicated train are traveling to the same destination, dedicated trains usually bypass classification yards. Layover times en route are usually minimal which may result in much shorter travel times for the goods being shipped by dedicated train. (Moore, 2003)

Compared with regular train, the advantages of dedicated train include:

Operational

Dedicated rail shipments can move unimpeded through the national rail system without intermingling with other rail traffic.

Safety

Dedicated trains may be expected to be involved in fewer accidents due to the uniform speeds that permit the train to move at a relatively constant speed without frequent braking and acceleration. The use of dedicated trains will also reduce accident frequency by enabling railroads to more effectively manage their system to ensure the train avoids congested locations. (Dilger, 2006)

Security

The security of these shipments will be improved due to the tighter controls exercised over the shipments en route. The ability to effectively select and screen train crews will also be enhanced by using dedicated trains. By aggregating shipments and hence reducing their numbers-security will be enhanced. The shipments themselves may also be hardened when they have been aggregated and points of particular vulnerability can be identified and mitigated when routes are known and arrival and clearance times are available. (Dilger, 2006)

Planning

Using dedicated trains makes it possible to more precisely predict the flow of Spent Nuclear Fuel and High-Level Radioactive Waste shipments through the national rail system-instead of a flood of separate individual rail cars throughout the rail system.

Inland waterway:

Also barges are suited for large loads, making them well suited for bulk transport. Barge transport is the slowest of the three but one ship can be capable of transporting up to 500 TEU, so large shipments are possible keeping cost to a minimum. If time is not an issue and the necessary infrastructure is available than transport by barge is a very good option

Once the container arrived at the sea port (in Figure 2-3), the containers are handled with various types of equipment like gantry cranes. Container terminals are very complex and busy places. Generally speaking after the container has arrived at the terminal, the container will have to wait in the container terminal for some time, containers are stored in stacks. The capacity, equipment and inland connection has a large impact on the services level of the terminal. In the following chapters, more detail introduction will be given about the sea port.

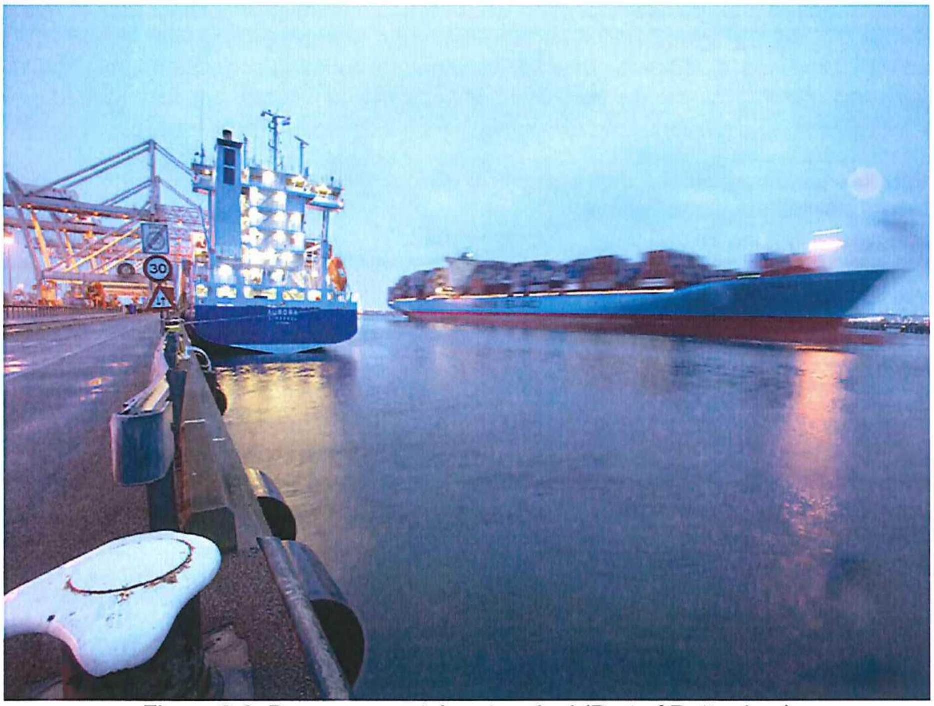


Figure 2-3: Deep sea container terminal (Port of Rotterdam)

After the ship is loaded it can leave the port. During the deep sea transition, the vessel may call on one or more ports to load or unload cargoes before setting of to the destination ports. The ships travel by fixed routes, which are heavily navigated by ships from all over the world.

When the ship arrives, the loaded container will be transported to the consignee directly or to the inland container terminal (seeing figure 2-4).

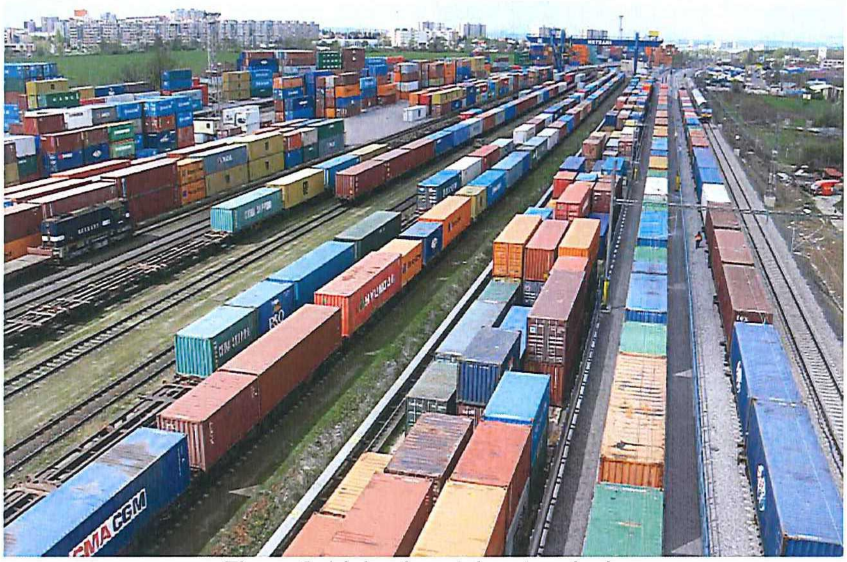


Figure 2-4 Inland container terminals

The main function of the inland container terminals is to transship containers between transport modes and provide a location where time consuming processes can be carried out. In essence, the inland container terminal is the seaport on dry land. It handles the same functions as a seaport. This allows inbound containers or outbound containers originating inland to bypass the port, which is generally congested, and be processed near the consignee.

Then, the containers will be distributed to the locations where the consignee are by the three modalities mentioned above.

Finally, the empty container will be transported back to the empty container depot.

2.2 World container trade routes

International trade represents a growing share of global output, and growth in the trade is expected to outstrip overall growth in output for the foreseeable future. On the basis of current trends, international trade may grow to the equivalent of 30 percent of world output by 2010 (from its current level of around 15 percent) (Theo Notteboom, 2007). It is the result of the booming of the global economy. Generally speaking, there are two kinds of important trade routes. One is on the regional level, such as European Union (EU) Single Market, North American Free Trade Agreement (NAFTA), or Far East Single Market. And the other one is on the global level, which is supported by the continuing development of World Trade Organization (WTO).

In the past thirty years, an important modification had taken place in the international trading flows. The size of international trade occurs within economic blocks, especially the EU and NAFTA. And the other important trade routes are between Asia-Pacific and North America, between Europe and North America and also between Europe and Asia-Pacific.

In the last decade, after the Asian financial crisis in the summer of 1997, most of the East Asia countries got an unprecedented economic growth. This economic booming transforms the patterns of world trade. These countries play a more significant role in the world market. As one of the world's most rapidly growing economies, China has achieved an average GDP growth of 9 percent, which it has been able to maintain since 1979. Shipping lines are dedicating higher capacities and deploying larger vessels to cope with increasing Chinese containerized imports and exports (Yap, Lam, & Notteboom, 2003). And the Chinese effect has also resulted in changes to the ranking of the world's largest ports, which can be found in the table 2.1.

Table 2.1 World port ranking in 2006

TOTAL CARGO VOLUME, MILLIONS OF TONS					CONTAINER TRAFFIC (TEUs, 000s)			
RANK	**PORT**	**COUNTRY**	**MEASURE**	**TONS**	**RANK**	**PORT**	**COUNTRY**	**TEUs**
1	Shanghai	China	MT	537.0	**1**	Singapore	Singapore	24,792
2	Singapore	Singapore	FT	448.5	**2**	Hong Kong	China	23,539
3	Rotterdam	Netherlands	MT	378.4	**3**	Shanghai	China	21,710
4	Ningbo	China	MT	309.7	**4**	Shenzhen	China	18,469
5	Guangzhou	China	MT	302.8	**5**	Busan	South Korea	12,039
6	Tianjin	China	MT	257.6	**6**	Kaohsiung	Taiwan	9,775
7	Hong Kong	China	MT	238.2	**7**	Rotterdam	Netherlands	9,655
8	Qingdao	China	MT	224.2	**8**	Dubai	United Arab Emirates	8,923
9	Busan	South Korea	RT	217.9	**9**	Hamburg	Germany	8,862
10	Nagoya	Japan	MT	208.0	**10**	Los Angeles	United States	8,470
11	Qinhuangdao	China	MT	204.9	**11**	Qingdao	China	7,702
12	South Louisiana	United States	MT	204.6	**12**	Long Beach	United States	7,289
13	Kwangyang	South Korea	MT	202.4	**13**	Ningbo	China	7,068
14	Houston, TX	United States	MT	201.5	**14**	Antwerp	Belgium	7,019
15	Dalian	China	MT	200.5	**15**	Guangzhou	China	6,600
16	Shenzhen	China	MT	176.0	**16**	Port Klang	Malaysia	6,326
17	Antwerp	Belgium	MT	167.4	**17**	Tianjin	China	5,950
18	Chiba	Japan	FT	167.0	**18**	New York/New Jersey	United States	5,093
19	Ulsan	South Korea	RT	161.1	**19**	Tanjung Pelepas	Indonesia	4,770
20	New York/New Jersey	United States	MT	143.0	**20**	Bremen/Bremerhaven	Germany	4,450

Abbreviations: MT=Metric Ton. HT= Harbor Ton. FT=Freight Ton. RT = Revenue Ton.

NOTE: The cargo rankings based on tonnage should be interpreted with caution since these measures are not directly comparable and cannot be converted to a single, standardized unit.

Sources: Shipping Statistics Yearbook 2007;
Containerization International Yearbook 2008;
U.S. Army Corps of Engineers, Waterborne Commerce of the United States CY 2006;
AAPA Surveys;
Various port authority internet sites.

And in European parts, the western markets are becoming mature. The total volume in Europe's most important countries and in the traditional market sectors are showing moderate growth rate. In the Central and Eastern Europe, the economic is expected a significant growth in the future. And for the northern ports, such as Hamburg, will get new development opportunities due to the expansion of the Europe Union.

2.3 New trends in the containerization

With the development of the global market and technology, and also due to the increasing of the fuel cost, there are several new trends in the shipping and the container terminal industry, which include:

- Scale increase in vessel size;
- Co-operation, mergers and acquisitions in the shipping;
- The emergence of global terminal operators;
- An increased focus on landside logistics; and
- Changes in liner service network design.

2.3.1 Scale increase in vessel size

The liner offers a regular, reliable and frequent service. And the cost is quit high and fixed. After the maritime network was built, the main issue is how to organize the freight transportation. In 1990s, due to the development of technology and rising in fuel price, a great deal of attention was move to larger, more fuel-economic vessels. Because the large vessels, which have more capacity, can produce a substantial reduction in cost per TEU compared with the smaller one. The changes in large vessel share can be found in table 2.2.

Table 2.2 Scale Increases in Vessel Size: Evolution of the World Cellular Fleet 1991–2006.

Source: BRS Alphaliner (2003)

	1991		1996		2001		2006*	
	Number	Shares	Number	Shares	Number	Shares	Number	Shares
>5000 TEU	0	0	30,648	1.0	621,855	12.7	2,355,033	30
4000-4999 TEU	140,032	7.5	428,429	14.4	766.048	15.6	1,339,978	17.1
3000-3999 TEU	325,906	17.6	612,377	20.6	814,713	16.6	892,463	11.4
2000-2999 TEU	538,766	29.0	673,074	22.6	1,006006	20.5	1,391,216	17.7
1500-1999 TEU	238,495	12.8	367,853	12.3	604,713	12.3	719,631	9.2
1000-1499 TEU	329,578	17.7	480,270	16.1	567,952	11.6	596,047	7.6
500-999 TEU	191,733	10.3	269,339	9.0	132,472	2.7	114,976	1.5
100-499 TEU	92,417	5.0	117,187	3.9	132,472	2.7	114,976	1.5
Total	1,856,927	100	2,979,177	100	4,907,503	100	7,847,593	100
*: Projection in January 2006 as compiled with existing fleet and order book as on 15 June 2003.								

In the future, larger vessel will be built for the same reason. The limitation will not be the technical or the operational, but the geographical, such as the size of Panamax vessels or (Virtual) Suez max.

2.3.2 Co-operation, mergers and acquisitions in the shipping

The main integration in liner shipping includes two types:

- Trade agreements, such as liner conferences or other operating agreements (a.o.

alliances)

- Mergers, take-over and Acquisitions (M & A).

The merger of P&OCL (already merger between P&O and OCL, early 1990s) and Nedlloyd in 1997 to become P&O Nedlloyd and the takeover of SeaLand by Maersk in 1999 is two of the well-known M&A activities in liner shipping. In 2005, a new level has been reached by the takeover. The P&O Nedlloyd became the third largest container shipping line, and the Maersk, was the world's number one. Now, the P&O Nedlloyd was taken over by Mearsk.

Table 2.3 Slot Capacity Operated by the Top 20 Shipping Lines (Thousands)

	January 1980 Carrier	Slot capacity	September 1995 Carrier	Slot capacity	January 2000 Carrier	Slot capacity	May 2005 Carrier	Slot capacity
1	Sealand	70	Sealand	196.7	AP Moller-Maersk	620.3	AP Moller-Maersk	1,051.4
2	Hapag-Lloyd	41	Maersk	186.0	Evergreen	317.3	MSC	687.6
3	OCL	31.4	Evergreen	182.0	P&O Nedlloyd	280.8	P&O Nedlloyd	464.8
4	Maersk	25.6	COSCO	169.8	Hanjin/DSR senator	244.6	Evergreen group	443.0
5	NYK line	24	NYK line	137.0	MSC	224.6	CMA/CGM Group	411.7
6	Evergreen	23.6	Nedlloyd	119.6	NOL/APL	208.0	NOL/APL	316.4
7	OOCL	22.8	Mitsui OSK line	118.2	COSCO	198.8	COSCO	299.5
8	Zim	21.1	P&OCL	98.9	NYK line	166.2	China shipping	298.6
9	US line	20.9	Hanjin shipping	92.3	CP ships/Americana	141.4	Hanjin/Senator	294.5
10	APL	20	MSC	89.0	Zim	136.1	NYK line	287.3
11	Mitsui OSK line	19.8	APL	81.5	Mitsui OSK line	132.6	OOCL	239.3
12	Farrell lines	16.4	Zim	79.7	CMA/CGM	122.8	CSAV Group	215.3
13	NOL	14.8	K-line	75.5	K-line	112.9	K line	213.3
14	Trans freight line	13.9	DSR-Senator	75.5	Hapag-Lloyd	102.8	Hapag-Lloyd	212.9
15	CGM	12.7	Hapag-Lloyd	71.7	Hyundai	102.3	Zim	211.1
16	Yang Ming	12.7	NOL	63.5	OOCL	101.0	Mitsui OSK line	205.7
17	Nedlloyd	11.7	Yang Ming	60.0	Yang Ming	93.3	CP Ships Group	195.2
18	Columbas Line	11.2	Hyundai	59.2	China Shipping	86.3	Yang Ming	185.8
19	Safarine	11.1	OOCL	55.8	UASC	75.0	Hamburg-sud	162.2
20	Ben Line	10.3	CMA	46.0	Wan hai	70.8	Hyundai	148.7
Slop capacity of top 20	435		2,058.1		3,538.1		6,544.0	
C4-indes (%)	38.6		35.7		41.4		40.4	
Share top 5 in Top 20 (%)	44.1		42.3		47.7		46.7	
Share top 10 in top 20 (%)	69.1		67.5		71.7		69.6	
Source: Compiled from various of BRS Alphaliner and Containerization International (1996, 2001, and 2006)								

The economic rationale for M&A is growth to achieve economies of scale, market share and market power. Other motives for M&A in liner shipping relate to gaining instant access to markets and distribution networks, obtaining access to new technologies or diversifying. The slot capacity operated by the top twenty shipping lines can be found in the table 2.3.

The top 20 carriers controlled 26 percent of the world slot capacity in 1980, 41.6 percent in 1992 and about 58 percent in 2005 (Theo Notteboom, 2007). They play a more and more important role in the world shipping market. One important factor is that most of the post-Panamax vessels are operated by these top 20 companies. As a result for this, their market share will keep increasing in the coming future, due to the large ship could reduce the cost of the shipping, so, these companies can offer a lower price service.

And beside this , another significant fact is that, most of the top 20 carriers are involved in multi-trade strategic alliances, such as the Grand Alliance (P&O Nedlloyd, OOCL, Hapag-Lloyd, NYK and MISC), the Cosco/K-Line/Yangming Alliance, the United Alliance (Hanjin and Senator) and the New World Alliance (APL, Hyundai and Mitsui OSK Lines). Those strategic alliances provide their members an easy access to more loops or services with relative low cost implications and allow them to share terminals and cooperate in many areas at sea and ashore, thereby achieving cost savings in the end. Mergers and acquisitions have led to the reshuffling of partners across alliances.

2.3.3 The emergence of global terminal operators

Facing to the development in the container shipping, the terminal operators choose different strategies to keep their competition position according to their scales. For those large companies, they prefer to increase their scale. For example, the P&O port is to join Hutchison, PSA and APM Terminals at the head of the global port operator league table. These companies have established a truly global presence, collectively operating in over 90 ports in 37 countries. In developing a global expansion strategy, HPH, PSA Corp, APM Terminals and P&O Ports try to keep a competitive edge by building barriers to prevent competitors entering their domains or succeeding if they do (Theo Notteboom, 2007). And for the smaller terminal operators, they have not been successful in neutralize the power of these large one. So, many of them avoid direct competition with the large companies by concentrating their market niches, for example in the short sea market.

Table 2.4 Global Terminal Operators' Presence in Europe

	Worldwide Throughput 2002	European Throughput 2002	European Throughput 1998	Annual growth Europe 1998-2002 (%)
Hutchson Port Holding (HPH) - China	36.70	6.9	7.75	-2.7
PSA Corp - Singapore	26.2	5.44	0.6	201.7
APM Terminal - Denmark	17.2	3.24	1.00	56.0
P&O Ports – UK	12.8	2.76	1.25	30.2
Eurogate – Germany	9.59	9.59	5.73	16.8
HHLA - Germany	4.00	4.00	2.35	17.6
Total of six major European container terminals operating companies	106.49	31.93	18.68	17.6
Grand total	275.00	46.50	35.06	8.2
Share six operators in grand total (%)	38.7	68.7	53.3	
Source: Based on the terminal operator data and Drewry Shipping Consultants (2003)				

As a result, the global container trade will concentrate in several big terminal operators. As can be found in the table 2.4, the Europe top six leading operators handle nearly 70% of the total European container throughput in 2002. And in 1998, the share is only 53%. These figures will keep increasing as a result of consolidation and building of new terminals. And it is estimated that, by the year 2008, the top four operators will control over one-third of total world container port capacity (Drewry Shipping Consultants, 2003).

On February 24, 2006, it was reported that there are 22 U.S. ports are taken over by

Dubai Ports World. According to the website of P&O Ports, the port-operations subsidiary of P&O, Dubai Ports World would take over stevedore services at 12 East Coast ports. Additionally, Dubai Ports World will take over P&O stevedoring operations at nine ports along the Gulf of Mexico. After this purchase, the Dubai Ports World became the third largest terminal operator in the world. And it also plans to build new terminals on the second Maasvlakte in 2013 or later.

2.3.4 An increased focus on landside logistics

From the viewpoint of a shipping line, inland logistics becomes one of the most vital areas in reducing the total costs. In a typical intermodal transport operation, inland transport now accounts for a much larger component of the cost than running the vessel. It is estimated that, the inland costs constitute 40–80 percent of the total costs of container shipping.

In traditionally, the carriers only focus on port to port transportation of goods. But in nowadays, they put more attentions to facilitate on logistics businesses in the area of just-in-time inventory practices, supply chain integration and logistics information system management. Till now, the most of the management of pure logistics service is between the companies who share the same mother company as the shipping line but operate independently of liner shipping operations.

The Maersk Sealand, the biggest shipping line in the world, have gone further in door to door services and integrated logistics packages, managing the container terminal operation, inland transport, and bypassing the freight forwarder by developing direct relationships with the shipper. And other shipping companies are also trying to enhance network integration through structural or get coordination with independent inland transport operators and logistics service providers.

Then, a group of shipping companies combined a strategy of selective investments in key activities with subcontracting of less critical services. They generally do not own inland transport equipment. Instead they attempt to use trustworthy independent inland operators' services on a (long-term) contractual basis.

The formation of global alliances has taken inter-carrier cooperation to a new stage, with members sharing inland logistics information, techniques and resources as well as negotiating collectively with suppliers. By extending to the landside logistics, those companies use a clearly different way to operate agreements. Inland and container logistics thus constitute an important field of action for shipping companies. Lines that are successful in achieving cost gains from smarter management of inland and container logistics can secure an important cost savings advantage.

At the same time, some of the terminals operating companies are also developing diverging strategies towards the control of larger parts of the supply chain. The door to door philosophy has transformed a number of terminal operators into logistics organizations. The services offered include warehousing, distribution and low-end, value-added logistical services. But not every terminal operator is integrating by acquiring or setting up separate companies or business units. In many cases, effective network integration is realized through better coordination with third-party transport operators or logistics service providers.

2.3.5 Changes in liner service network design

The network design has also changed. In the past, the network design is more focus on the pure cost-driven exercise. The optimal network design is only a function of carrier-specific operational factors. Now, it moves to a more customer-oriented differentiation exercise. More attention have been put on shippers' needs (for transit time and other service elements) and of shippers' willingness to pay for a better service.

The alliances and consolidation have created multi-string networks on the major trade routes and both shippers and liners are used to it. As service network design has become a more customer-oriented differentiation exercise, this could very well introduce a tendency towards less transshipment and more direct ports of call (even for the bigger vessels).

In a word, the shipping companies are gradually shifting from pure shipping operations to integrated logistics solutions. Through various forms of integration along the supply chain, shipping lines are trying to generate revenue, streamline sea, port and land operations and create customer value. For the time being, container terminal operators are mainly focused on increasing the scale of operations. In some cases, port authorities are also extending their activities to inland terminals, e.g. Duisburg, Germany. Global terminal operators clearly have shifted their mindset from a local port level to a port network level, albeit that the terminal network effects still have to be exploited to the full.

2.4 Actor analysis

As mentioned in 2.1.2, the general process of containerization can be described in following figure 2-5.

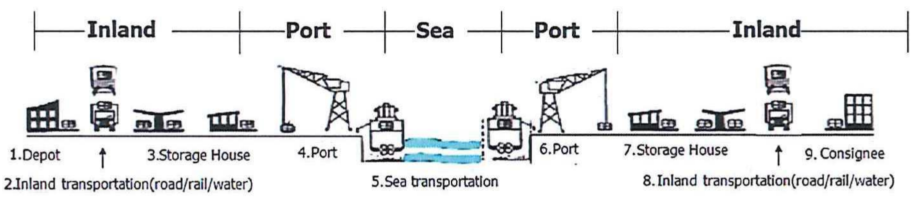


Figure 2-5 General transportation process in containerization

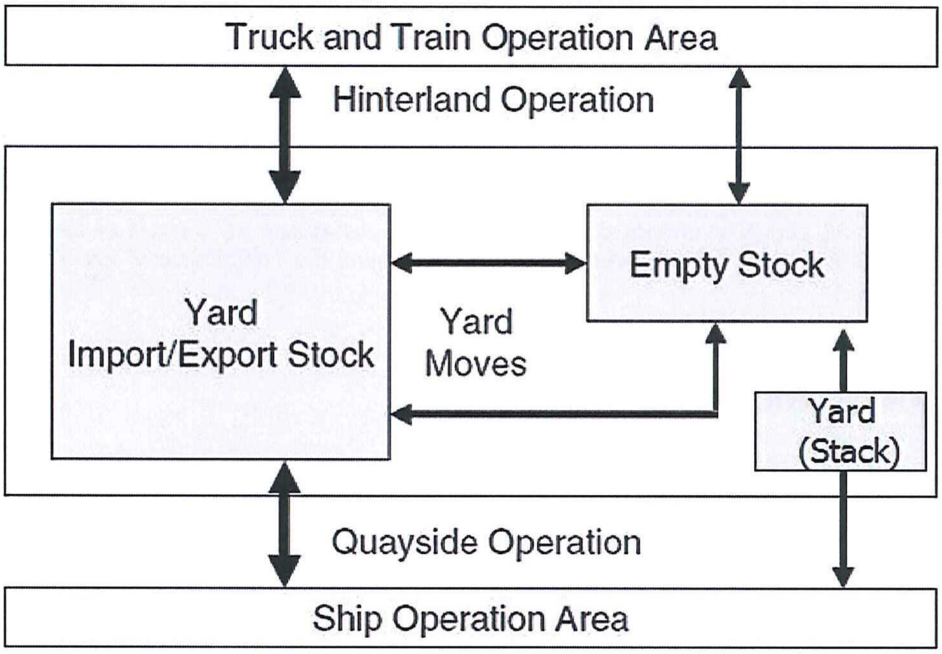
The actors in this flow may include manufacture and consignee, inland transport operators, port authority, terminal operator, shipping company, and so on.

2.4.1 Terminal operator

A port operator is the port authority or company that has contracts with the port authority to move/transship cargo through a port at a contracted minimum level of productivity (AAPA). They may be state-owned (particularly for port authorities) or privately run. Their work involves managing the movement of cargo containers between cargo ships, trucks and freight trains and optimizing the flow of goods through customs to minimize the amount of time a ship spends in port. Maintaining efficiency involves managing and upgrading gantry cranes, berths, waterways, roads, storage facilities, communication equipment, computer systems and dockworkers' union contracts. The port operator also manages paperwork, leases, safety and port security.

In general terms, container terminals can be described as open systems of material flow with two external interfaces. These interfaces are the quayside with loading and unloading of ships, and the landside where containers are loaded and unloaded on/off trucks and trains. Containers are stored in stacks thus facilitating the decoupling of quayside and landside operation.

After arrival at the port, a container vessel is assigned to a berth equipped with cranes to load and unload containers. Unloaded import containers are transported to yard positions near to the place where they will be transshipped next. Containers arriving by road or railway at the terminal are handled within the truck and train operation areas. They are picked up by the internal equipment and distributed to the respective stocks in the yard. Additional moves are performed if sheds and/or empty depots exist within a terminal; these moves encompass the transports between empty stock, packing center, and import and export container stocks. The operation areas of a seaport container terminal and flow of transports can be found in the figure 2-6.



(Source: Dirk Steenken, 2004)

Figure 2-6 Operation areas of a seaport container terminal and flow of transports

2.4.2 Port authority

The port authority is a governmental or quasi-governmental public authority for a special-purpose district usually formed by a legislative body (or bodies) to create and support economic development within that area. (Wikipedia)

Port authorities are usually governed by boards or commissions, which are commonly appointed by governmental chief executives, often from different jurisdictions. For example, in Canada the federal Minister of Transport selects one board member, the local chief executive one and the rest of the board are at the recommendation of port users to the federal Minister. In Canada all port authorities have a federal or Crown charter called

Letters Patent. (Rexford B. Sherman)

Most port authorities are financially self-supporting. In addition to owning land, setting fees, and sometimes levying taxes, port districts can also operate shipping terminals, airports, railroads, and irrigation facilities. But for some areas, such as Hamburg-Le Havre range, the fierce competition puts pressure on cost recovery of investments. So, they need to put more attention on the competition strategies.
The port authority is one of the main actors in the port competition. Because they need to make the decision whether the port capacity is need to be expansion or not. And they need to choose the best expansion strategies. As mentioned in the chapter 1, the main problem in port capacity is not only shortages in capacity, but also sometimes over-capacity. So, they must to consider the port demand fluctuation causing by temporary peak loads and the utilization ratio at the same time.

2.4.3 Shipping company

Shipping Companies are charged with the movement of goods from one place to another by sea. Normally they own their vessels and containers. Transport over sea almost always takes place under the carrier's management.

As mentioned in the 2.3.2, there are more and more large shipping companies in the market. And only those large one can dominant the market. So, lots of co-operation, mergers and acquisitions take place between companies. And as a result of this, the shipping company will have more powers on determine the container flow and supply chain.

2.4.4 Inland transport operators

Inland transport operators (the road, barge and rail operators) are the people who charge the container transport. Their business depends on the transport times between origin and destination (ECMT, 2000).
In nowadays, the main battlefield in port competition is on the inland transportation. How to choose the optimal inland transport network is one of the most important issues for most shipping companies. So, for the ports serviced for the same inland area, a better inland connection can offer them a strong competition position.

2.4.5 Manufacture and consignee

A factory is an industrial building where workers manufacture goods or supervise machines processing one product into another. It is the start point of supply chain.

The consignee is the person to whom the shipment is to be delivered whether by land, sea or air. It is the end point of the supply chain.

It is hard to regulate the mass transportation industry which cannot always guarantee the goods arrival on time or those goods will not be damaged in the course of transit. A further two problems are that unpaid consignors or freight carriers may wish to hold goods until payment is made, and fraudulent individuals may seek to take delivery in place of the legitimate consignees. The key to resolving such disputes lies in the documentation. For the maritime trade, three main agreements are used: FOB (Free On Board), CIF (Cost , Insurance and Freight), CRF(Cost and Freight).

In CIF, the manufacture could choose use the third part to deliver the goods, which is called carrier haulage. And also, the can choose arranging the transportation by themselves, it calls merchant haulage. In recent years, more manufactures prefer to choose merchant haulage way, due to the low cost. As a result, the manufacture and consignee also can choose which port will be used in the transportation. So, they can influence the port competition.

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3 Dynamic port planning

In this chapter, the system of dynamic port planning will be described. In section 3.1, the background of the dynamic port planning will be given. In section 3.2, the main issues will be analyzed. Based on this analysis, the existing approach and further expansion will be developed in section 3.3.

3.1 Dynamic port planning

As mentioned in the previous chapters, in the middle of the competitive struggle between shipping companies and terminal operators, a decrease of the market power of port authorities can be noticed (Gerrits, 2007). As a result of this, port authorities have to make strategic decision in the face of strongly growing market and volatile demand. The investment decision making has to incorporate scale effects, congestions, competition, hinterland transport, and a financing and pricing which has to account for an increasing privatization of port operations. To strengthen the market power of port authorities, they need to be provided with a tool to optimize the decision making.

Generally, port expansion requires huge investments. Because of these huge investments, port authorities try to reduce the risk by making a good port planning. Port planning enables port authorities to develop a strategy to reach their objectives and goals in an efficient way. But, the port planning is a very complex process because ports are a part of a dynamic system. The priorities of port users are subject to fast changes, even more stimulated by technological developments. Dynamic port planning helps port authorities to adopt and anticipate on the demands of the container transport market. Also land reclamation/infrastructure is very time-consuming planning procedures.

3.2 Main issues in planning of port capacity

3.2.1 Port capacity

Basically, a port is an interface of land and water where ocean vessels can be loaded and unloaded, cargo can be stored, and where hinterland transportation modes can collect and deliver cargo (Van de Voorde and Winkelmans, 2002). In additional, a port can be considered as a link in global transport-logistic chain connecting origins and destinations for freight flows (Suykens and Van de Voorde, 1998)

As mentioned in the Chapter 1.1.1, the port capacity is the maximum cargo handling capacity, it will be measured by the number of containers that can be handled per year (for container port). Port capacity is the combination product of port facilities, such as land, infrastructure, superstructure, and maritime and hinterland access infrastructure and associated services. These services are mainly mean cargo handling services, which are provided with the help of port facilities.

The following issues complicate the planning of a port's capacity (Dekker, 2005):

- Port-commercial and public interests;

- Competition;
- Economies of scale;
- Capacity problem; and
- Port market and technological development
- Hinterland infrastructures

Interaction between these issues and between different ports will make planning for port even more complicated. These issues will be discussed in short below.

3.2.2 Port-commercial and public interests

When making port capacity planning, three actor need to be distinguished.

First, there is a port owner who provides port capacity. His interest can be considered from the port-commercial perspective. The interests associated with the port-commercial perspective include: maximization of profit, maximization of throughput and recovery of the investment cost.

Second, there are port users who demand efficient port services, such cheap, fast services. They represent the freight carriers who choose between the different ports.

Third, the society, which desires the presence of ports because of their contribution to quality of life and social-economic development, is also need to be taken into account. Besides, society sets limits for negative effects of port usage such as environmental pollution.

The interests of port users and society are considered from the public perspective.

The port planner's task is to determine the optimal port capacity to deal with competition and to facilitate further growth of demand. His aim is overall viability of the port expansion project by integrating public interests and the port-commercial interest.

From the public perspective, port capacity can be determined by finding a balance between improved service quality for the port users and welfare effects on society on one hand, and the associated investment cost of capacity improvement on the other hand. In addition a realistic planning has to consider the commercial interests of the port owner (Dekker, 2005).

3.2.3 Port competition

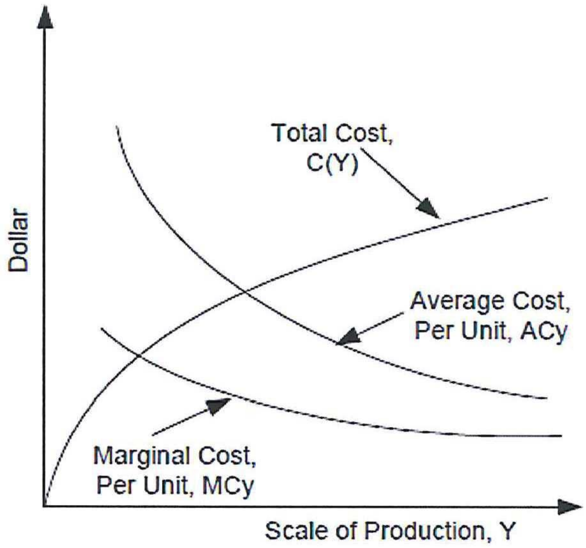
As explained in paragraph 1.2, there are different levels of port competition. With a view on the overall objective of this thesis - to provide port authorities a tool to optimize its strategic decision making – this study focus on inter-port competition at the level of authorities. At this level, ports operate as nodes in the global transport-logistic chains connecting origins and destinations for freight flows as conceptually shown in figure 1-1.

The manufacture and consignee could choose any port with a different cost in the oversea transport and hinterland transport and port due. Due to the competition ports are always in the same region, the transportation cost for the sea will be almost the same. So, the cost of the hinterland transport and port due will influence the decision making. And also, the service level in each port is a significant factor.

3.2.4 Economies of scale

Economies of scale exist for a production process when it is cheaper to produce in quantity. Formally, they exist when the average optimal cost per unit of output decreases as the level of production increases. The increase in efficiency of production as the number of goods being produced increases. Typically, a company that achieves economies of scale lowers the average cost per unit through increased production since fixed costs are shared over an increased number of goods.

There are two types of economies of scale:
External economies - the cost per unit depends on the size of the industry, not the firm.
Internal economies - the cost per unit depends on size of the individual firm.
As illustrated in figure 3-1, the concept of economies of scale is closely related to-but different from that of increasing returns to scale. Both refer to the idea of somehow getting proportionately more as the scale of production increases. Their principal difference arises from the fact that the notion of economies of scale incorporates information about the input cost function, $C_{(x)}$. The form of this function can thus affect the effect of increasing returns to scale.



(Source: Reader for CT4701)

Figure 3-1 General relationship of total, average, and marginal costs of production for a process with economies of scale

A port needs to determine the net effect of its decisions affecting its efficiency. Thus, while a decision to increase its scale of operations may result in decreasing the average cost of inputs (volume discounts), it could also give rise to diseconomies of scale if its subsequently large port capacity is inefficient because not enough hinterland infrastructure were invested in as well. Thus, when making a strategic decision to expand, ports need to balance the effects of different sources of economies of scale and diseconomies of scale so that the average cost of all decisions made is lower, resulting in greater efficiency all around.

3.2.5 Capacity problems

As mentioned in section 1.1.2, there are two kinds of capacity problem that occurs as a result of the dynamics of competition, one is the shortages in capacity and another one is over-capacity.

To make sure the port in a better competition position, a certain amount of over-capacity is required. Otherwise, in the short term, port demand may fluctuate causing temporary shortages in capacity due to peak loads. So, the extra capacity is needed. At the same time, the over-capacity could make the utilization ratio low. It is quite important that make a balance between extra capacity and utilization rate when the port authorities making the port capacity planning.

3.2.6 Port market and technological development

It is said that, the growth in international container shipping will continue with the expected percentage of 9% annually up to 2015 (Heymann, 2006). The port markets will also growth with the international container shipping. That is to say, for port authorities, they will also facing the problem with capacity expansion.

The competition position of ports will be change due to the technological development. The development and application of new technology can improve service levels, such as using fast cargo-handling facilities to reduce port service times. Those new technologies can reduce the total cost of the port and even change the organization of port.

3.2.7 Hinterland infrastructure

The ever-increasing container transport volumes handled in seaports have put the issues of hinterland transport capacity and performance on the agenda of seaports. Substantial cost reductions in deep-sea container transport in the last decades have shifted the attention of shippers to inland operations: in many cases hinterland services have the largest share in the total transport bill.

The development of intermodal transport has given a new dimension to the hinterland transport issue. It can help keeping the port accessible by shifting cargo away from the congested roads to the waterways and railways. On the other hand the large transport volumes in seaports generate scale economies to operate cost efficient hinterland services to different destinations, which enable seaports to strengthen their hinterland position (Konings, 2007).

3.3 Existing approach for planning

3.3.1 Network design

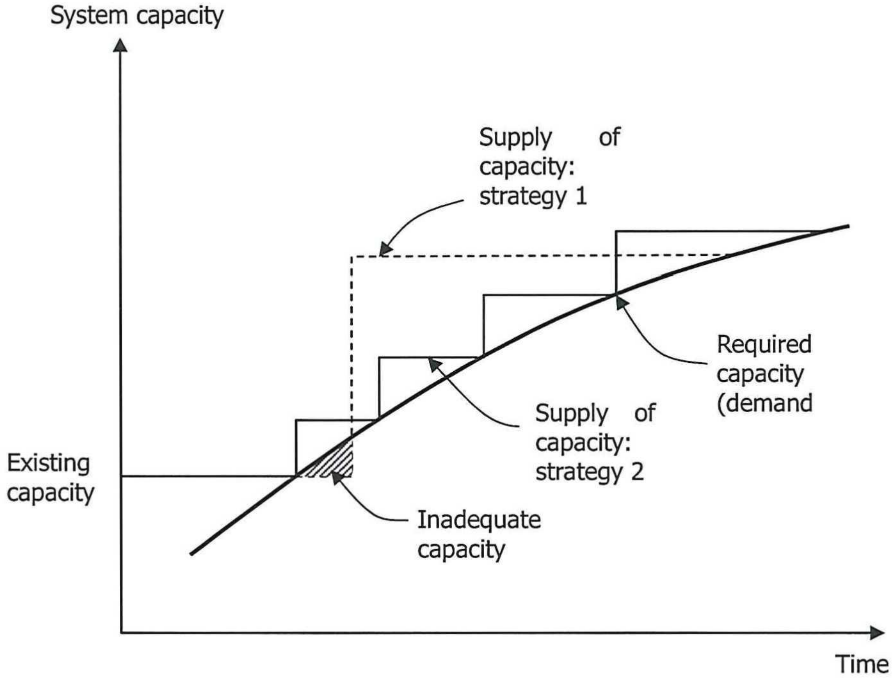
Containerization has changed liner shipping spectacularly and affected seaports and their hinterland transport systems (Langen and Chouly, 2004). Container shipping has enabled new kinds of liner service networks such as the hub-and-spoke formation, putting pressure on the performance of hub ports and the feeder networks to these ports over sea and land.

Containerization has increased the geographical market coverage of seaports to the extent that the concept of a captive hinterland is no longer valid (McCalla, 1999). Ports are much more in competition to serve the same inland areas. Especially in Northwest Europe, where the distance of container ports to major cargo generating inland areas is not a very distinguishing factor, this has made hinterland accessibility a strategic matte.

3.3.2 Capacity expansion

The demand for additional capacity will often be growing gradually so that it is possible to stage the construction of facilities over time. While it is clear that substantial additions capacity will be required in a long time, these do not all have to be built now. The number of cranes and the total hectare of the port can be increased incrementally, since the demand for their output is also growing gradually.

The ultimate capacity for systems whose loads are increasing incrementally can be provided in a number of steps. As an illustration, two possibilities are shown in Figure 3-2. The graph shows the projected future requirements as well as two strategies for adding on the ultimate capacity needed. In general, a wide variety of plans for the expansion of capacity could be formulated. Each of these will alter the time stream of costs and benefits and provide a different net present value of the benefits. The wide variety of possible designs indicates the scope of the capacity expansion problem, which is to determine the optimal strategy for adding capacity to a system.



(Source: Reader for CT4701)

Figure 3-2 Different strategy for capacity expansion

The optimal strategy for capacity expansion is the one which minimizes net present total costs of providing the required system capacity.

The total costs consist of three elements (Source: Reader for CT4701):
(1) The construction costs,
(2) The opportunity costs of the capital invested in capacity, and
(3) The costs or penalties paid for inadequate capacity.

Due to the time value of money there is a strong pressure to defer construction costs as far into the future as possible. If the cost per unit of capacity addition is fixed regardless of the size of facility built, then the optimal strategy is to merely add capacity continuously in small increments as requirements increase.

3.3.3 Scale effect

The optimum interval between additions to capacity can be calculated as elaborated below. The expression for the costs of capacity addition can be written as:

$$f(xD) = K(cD)^{\alpha}$$

Where $0 < \alpha < 1.0$ when there are economics of scale. The total cost function can then be rewritten as:

$$C(x) = \frac{K(xD)^{\alpha}}{1-e^{-rx}}$$

Differentiation with respect to x, and setting equal to zero yields an expression defining the optimum interval $x*$:

$$\frac{rx*}{e^{rx^*}-1} = \alpha$$

As can be seen from this equation, the optimum interval between capacity expansions is independent of the rate of growth of demand D. It depends only on the discount rate and the scale factor α. This clearly indicates that the optimal strategy for capacity expansion is determined by the trade-offs between economies of scale and the opportunity cost of capital.

3.3.4 Transportation demand modeling

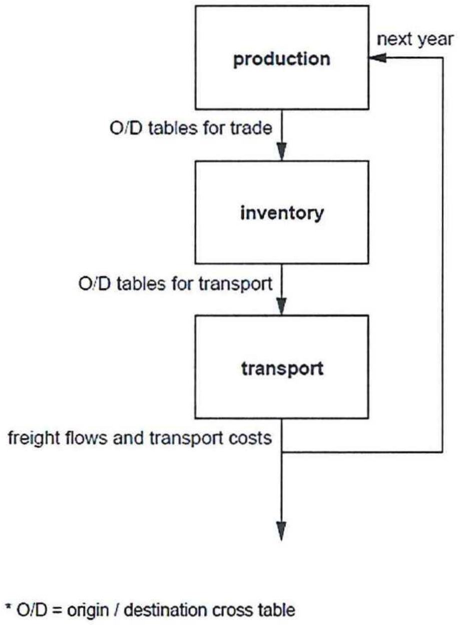
As showed in figure 1-1, port capacity planning requires schematization of a port as node in a transportation network. A port reacts on developments elsewhere in the network such as the entering of a new route via a competing port. The effect of the reaction, in this study, it is mainly capacity expansion, on the port's competiveness can then be analyzed by transportation modeling.

Basically, two approaches for modeling transport can be used in transportation planning concerning the port capacity problem:

- Simulate of route assignment in a network.

An example is the SMILE model (Strategic Model for Integrated Logistics and Evaluation) as developed by the Dutch institute TNO, which simulates the assignment of freight flows for different commodity types and transportation modes (see, e.g., Tavasszy, 2003);

The Strategic Model for Integral Logistics and Evaluation (SMILE) was developed for the government's Transport Research Centre. SMILE forecasts the flow of goods in and around the Netherlands, up to decades in advance. The structure of SMILE can be found in figure 3-3.



(Source: Lóránt Tavasszy)

Figure 3-3 SMILE structure: dynamics

SMILE is unique in the way the product networks of a large number of goods types are translated into homogeneous product groups, the so-called Logistics Families. It can estimate the locations and size of intermediate stocks in the chain. Economic growth scenarios and policy scenarios for goods transport form the input for the model. The output is the goods transport forecast, detailed per year, 40 regions in the Netherlands, 50 goods groups and 12 transport methods.

- Projection of port demand based on macro-economic relationships with a more or less fixed market share for the particular port.

An example is the GSM model (Goederen Stromen Model) as used by the Port of Rotterdam for long-term demand projections, particularly for container flows. (The latest vision of GSM model has already includes land use predictions)

The first approach is not accounting for port development. The main focus is on the hinterland transportation network. So, the port investment characteristics are not taken into account. The second approach accounts for port development, but do not incorporate potential changes in a port's market share due to, for instance, competition between transportation routes.

So, a new model is needed which can combine both approaches and used to simulate the effect of competition and to incorporate autonomous demand growth. This model needs to take port development (mainly port capacity expansion), growth in hinterland infrastructure, and changes in market share into account.

The new model will be introduced in Chapter 4.

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4 Port competition model

In this chapter, the new port competition model will be developed. In section 4.1, there will be a short introduction of the model used in the previous research, including its usage and its limitation. And based on it, a new model will be made in section 4.2.

4.1 General introduction

As mentioned in the previous chapters, the port expansion strategy is a quite complexity issue. Not only the factors that could determined by port authorities, such total port capacity, utilization ratio, need to be taken into account, but also issues that beyond the control of port authorities, such as global economic growth, hinterland infrastructure growth, could influence the decision. And in the competition environment, the interaction of different port strategies will make the decision making more complex.

In order to find a better strategy considering all the aspect and uncertainties, simulation is wildly used in making port planning. Many models are made in this purpose. Basically, two approaches for modeling transport can be used in transportation planning concerning the port capacity problem:

- Simulate of route assignment in a network.

An example is the SMILE model (Strategic Model for Integrated Logistics and Evaluation) as developed by the Dutch institute TNO, which simulates the assignment of freight flows for different commodity types and transportation modes (see, e.g., Tavasszy, 2003).

- Projection of port demand based on macro-economic relationships with a more or less fixed market share for the particular port.

An example is the GSM model (Goederen Stromen Model) as used by the Port of Rotterdam for long-term demand projections, particularly for container flows.

The first approach is not accounting for port development. The second approach accounts for port development, but do not incorporate potential changes in a port's market share due to, for instance, competition between transportation routes. But these two are the significant factor in the port capacity expansion. So, a new model which is combined all the factors mentioned above will be made in this study.

In this new model, a new concept that considers the port as a node in the logistic chain is used. The port development and hinterland infrastructure growth will make the port competition in a dynamic system. The changes in both aspects will influence the decision making. Due to the high market share is the main objective for port authority. The market share will be used as a main output in the model. Other output includes utilization, volume, and unit cost of each port. And at the same time, thirty iterations will be used in the model. The cycle time is one year. That is to say, the calculations will be thirty years ahead. In iteration, the output of the previous one will become the input of the new one. The feedback of the market share will be used as the new input in the next iteration. The market share is determined by the total unit cost (i.e. generalized costs) for the alternative logistical chains. The total unit cost includes:

- Hinterland transport cost and congestion, which determined by the hinterland infrastructures;

* Port residence cost and congestion, which determined by port utilization ratio; and
* Port investment cost, which determined by port capacity.

At the same time, the new demands of the port are determined by the market share and total demand, which will be influenced by the global economy development. The development in demand influence the utilization ratio, port investment cost, and hinterland transport cost and congestion. The conceptual system diagram for the modeling of port competition can be found in the figure 4-1.

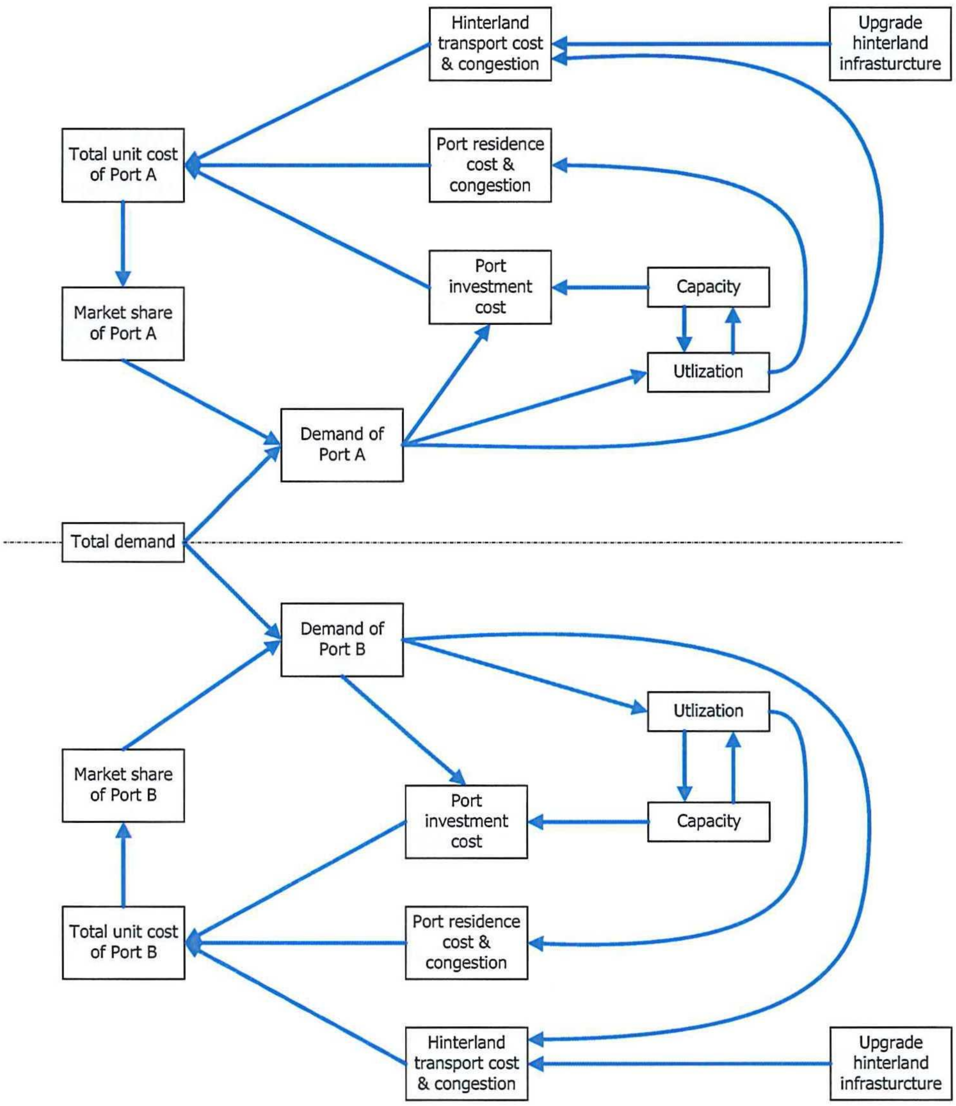


Figure 4-1 The conceptual system diagram for the modeling of port competition

This model is developed based on the following iterative mechanism: In one year, these three aspects (i.e. port residence cost, port investment cost, and hinterland transport cost) determine the unit transshipment cost per TEU of this same year and ultimately determine ports' market share of the same year. However, the market share of this year would determine the three costs of the next following year (i.e. port residence cost, port investment cost, and hinterland transport cost).

Compared with the two transportation planning model mentioned above (SMILE and GSM), the difference between them can be found in table 4-1.

Table 4-1 The comparison of SMILE, GSM and New Model

	Port development	Changes in market share	Hinterland transport	Hinterland infrastructure growth
SMILE	Out	Out	In	In
GSM	In	Out	In	In
New Model	In	In	In	In
"In" means the factor has been taken into account; and "Out" means the factor has not been taken into account yet.				

In the following section, the existing model will be first analyzed. Then, the limitation of the existing one will be given. And based on the limitations, the model will be further expansion.

4.2 Recent developed methodology

The overall objective of the previous study is to support strategic planning of a node in a transportation service network, which is characterized by competition. In 2005, a PhD study was completed concerning the development of a methodology for planning of port capacity anticipating on the increasing competition between European ports with relation to the container market (Dekker, 2005)

4.2.1 Brief summary

The study contributed to that objective by the development of a methodology for planning of port capacity in which modeling of the system and application of economic concepts are major components. The challenge was to integrate port-commercial and public interests in such methodology, and to incorporate competition, autonomous growth of demand, economies of scale and technological development.

4.2.2 Description of model components

The model components from the conceptual systems diagram for the modeling of port competition are described as follow:

Market share
In this research the assumption is made that the market share of port is mainly determined by the generalized unit cost of the logistical chain where he makes part and the generalized unit cost of logistical chains, serving the same hinterland, where other ports make part of.

The total demand is assigned to the different ports using the discrete choice model:

$$Q^i_{anm} = \frac{Q^i_{am} \bullet \exp(-\mu \bullet GC^i_{anm})}{\sum \exp(-\mu \bullet GC^i_{anm})}$$

With Q^i_{am}: Number of containers for commodity group i that moves from a to m and use port n.

GC^i_{anm}: Total generalized cost for transporting commodity group i by using the nth port

μ: Spreading parameter

Total unit cost

The discrete choice model is based on the total generalized cost per TEU to assign the total demand to the different ports. This unit cost is composed of:

- A cost for recovery of port investment
- A cost associated the time spend in the port, including congestion
- A cost associated with hinterland transport, including congestion.

Port investment cost

Maritime transportation is beyond the scope of this research and the costs for maritime transportation are therefore left out of consideration. The competition between port in a port cluster region is only in port investment cost, port congestion cost and hinterland transportation cost. The costs for port usage C_n are:

$$C_n = pd_n + tc_n$$

It is assumed here that port expansion can be self-financing and that the port investment cost can be fully recovered by port dues and terminal charges.

For the sake of simplicity, port dues pd_n and terminal charges tc_n are assumed to be independent from vessel size and dwell time.

Port residence cost and congestion cost

The total number of days spends in the port:

$$D_n = H_{nd} = t_{ff,n}$$

The average time for container discharge H_n is here assumed to be independent from the throughput and capacity, suggesting there is no port congestion.

The time cost of port usage is approximated by the opportunity cost of time OC^i:

$$OC^i(D_n) = V_i \bullet \rho \bullet D_n \quad \text{With} \quad V_i \bullet \rho = VOT$$

$$OC^i(D_n) = VOT \bullet D_n$$

Including private congestion cost:

$$t_n = t_{ff,n} \bullet \left(1 + c \bullet \left(\frac{Qn}{Kn}\right)^k\right)$$

$$OC^i(D_n) = VOT \bullet t_{ff,n} \bullet \left(1 + c \bullet \left(\frac{Qn}{Kn}\right)^k\right)$$

Including external cost:

$$OC^i(D_n) = VOT \bullet t_{ff,n} \bullet \left(1 + c \bullet \left(\frac{Qn}{Kn}\right)^k\right) + VOT \bullet t$$

Hinterland transportation cost & congestion cost

The cost for hinterland transportation via route r, C_{nmr} can be expressed with:

$$C_{nmr} = \sum_{j-1} p_t + \sum_j \beta_j \bullet I_{rj}$$

The total number of days spent in the hinterland transit for route r is:

$$D_{nmr} = H_{ndj} + \sum_j \frac{I_{rj}}{24 \bullet S_j} + \sum_{j-1} H_{tdj} = t_{ff,nmr}$$

The dwell time in a port H_{nd} and the dwell time at an inland terminal H_{tdj} are here assumed to be independent from the throughput and capacity, suggesting there is no port congestion.

The time cost of hinterland transportation is approximated by the opportunity cost of time, OC^i:

$$OC^i(D_{nmr}) = V_i \bullet \rho \bullet D_{nmr}, \text{ with } V_i \bullet \rho = VOT$$

$$OC^i(D_{nmr}) = VOT \bullet D_{nmr}$$

Including private congestion cost:

$$t_{nmr} = t_{ff}, nmr \bullet \left(1 + c \bullet \left(\frac{Q_{nmr}}{K_{nmr}}\right)^k\right)$$

$$OC^i(D_{nmr}) = VOT \bullet t_{ff}, nmr \bullet \left(1 + c \bullet \left(\frac{Q_{nmr}}{K_{nmr}}\right)^k\right)$$

Including external cost:

$$OC^i(D_{nmr}) = VOT \bullet t_{ff}, nmr \bullet \left(1 + c \bullet \left(\frac{Q_{nmr}}{K_{nmr}}\right)^k\right) + VOT \bullet t_{ff}, nmr \bullet c \bullet k \bullet \left(\frac{Q_{nmr}}{K_{nmr}}\right)^k$$

An envisaged further detailing of the model includes a specific modeling of the transportation network, including different transport modes using a joint modeling with a specific freight transportation model.

Utilization rate

An important variable is the utilization rate, defined as the ratio of actual flow through the port over capacity. The utilization rate forms the main input to determine port congestion. A new capacity expansion step is triggered when the utilization rate reaches a particular maximum threshold value. A certain amount of reserve is however necessary for peak load handling. A maximum utilization rate of about 90% is a frequently used value.

The utilization rate is a control variable decides the capacity planning: it may be decided to lower congestion levels in order to attract a larger market share.

Capacity expansion strategy

The capacity expansion strategy forms a main input to the modeling, one of the possibility is to use the "expanded Manne method", to determine the optimal expansion step, taking into account a progressive scale effect in combination with price-demand interaction.

Upgrade hinterland infrastructure

The hinterland connection is mainly represented by the distance from the port to the main hinterland centre and the cost of transport. A value for the utilization rate of the hinterland connections has to be adopted and the highway congestion formula (BPR formula) is used to compute congestion. A congested hinterland connection will have a strong effect on the competitiveness of the logistical chain. Therefore a gradual expansion of this hinterland capacity is incorporated in the simulation.

4.2.3 Data requirements for the existing model

This part will describe the data required for the model including the data needed for the improvements incorporated in the model. All required data concerns container transport.

4.2.3.1 Growing overall demand

- Data on actual (2005) throughput, capacity and utilization rate of different ports: Rotterdam and Antwerp;

- Actual (2005) total demand Rotterdam and Antwerp to determine market share in 2006;

- Forecast throughput volume Europe, Rotterdam and Antwerp for coming 20 to 30 years in container transport

4.2.3.2 Demand specific port

- Port dues and terminal charges for Rotterdam and Antwerp;
- Service and dwell times for Rotterdam and Antwerp;
- Specific modeling of the transportation network for different transport modes, with data on transportation cost, distance and duration including dwell times at inland terminals;
- Data on route choice (performance total chain for transportation via specific port: value of time, congestion, reliability, out of pocket costs, scope possibilities)
- Data on shipper choice for a specific port (qualitative and quantitative)
- Data on route choice and shipper choice is probably very difficult to acquire. It depends on the available data in what detail this aspect will be incorporated in the port competition model. If availability is poor the assignment of traffic will be based purely on the generalized unit cost of the logistical chain and allocation of freight flows is determined using the discrete choice model.

4.2.3.3 Upgrading hinterland infrastructure

Forecast growth hinterland infrastructure in the destination areas.

4.2.4 Limitations

Some limitations in the focus and content of this previous model are:
- Port investment cost

- Hinterland modal split

Port investment cost
In the basic model, the total port investment cost is divided by all the demand equally, as showed in the previous chapter:

$$Portinvestment\cos t = \frac{334 * Capacity^{0.6}}{Volume}$$

But in the real world, the market region for the port will be divided into two kinds of area, captive areas and fighting areas. For the captive area, the shipping companies have to use a certain port. So, the port authorities could ask them for the highest price that the shipping companies can offer. Then, the price for the shipping companies who transport goods to the fighting areas can be as cheaper as possible. As a result, the port can get a better competition position.

So, it is better to share different port investment cost depending on the whether the destination region is in the captive area or fighting area.

Hinterland modal split
In the basic model, the hinterland transportation cost is the function of Volume and growth hinterland infrastructure. For port of Rotterdam, the hinterland transportation cost:

$$Cost_{portofRotterdam} = 582 * 0.08 * (1 + 0.15 * \left(\frac{volume}{8.7 * growthh\operatorname{int} erland\inf ra} \right)$$

And for port of Antwerp, the hinterland transportation cost:

$$Cost_{portofantwerp} = 532 * 0.08 * (1 + 0.15 * \left(\frac{volume}{6 * growthh\operatorname{int} erland\inf ra} \right)$$

That is to say, there will be no difference for different destination area and modes. But in the real world, the cost will change dramatically, depending on the modalities.

In the following section, based on the previous research, and the limitation of the existing model, it will be expanded in these two areas mentioned above.

4.3 Port Competition model

In this chapter, the existing model will be expanded. The captive area and the modal split will be taken into account.

4.3.1 Captive area

Captive area is the region which is dominated by one port. That is to say, if the destination area is in the capital area of one port, the shipping companies have to choose that port. They do not have other choice.
But in the fighting area, the ports need to compete with each other. In this region, the shipping companies could choose different ports according to the cost and service level.

So, it is quite important for the port authorities to know which region is their capital area, and which one is the fight area. Then, they can make a different price for certain area. For the capital area, due to the shipping companies have only one choice, they can ask the highest cost that those companies can offer. Then, they can give a lower cost for the companies in the fighting area, in order to get a better position in the competition.

In table 4-2, the Continental hinterland flows in 1997 and 2001 was showed.

From Table 4-2, freights are transported from both ports to all the destination area. Due to the geographical location, it is quite hard to say which country is the captive area for Rotterdam or for Antwerp. The captive areas only exist in some certain small regions which are quite near the port region.

Table 4-2 The Continental hinterland flows in 1997 and 2001
(1000 TEUs (full and empty))

Year	Destination		Rotterdam					Antwerp				
			Road	Rail	Inland water way	Total	percentage	Road	Rail	Inland water way	Total	percentage
1997	Germany	Region Hamburg-Bremen	84	33	0	117	94.35%	7	0	0	7	5.65%
		Region Ruhr	541	48	441	1030	76.81%	141	6	164	311	23.19%
		Region East Germany	47	6	32	85	93.41%	6	0	0	6	6.59%
	Netherlands		1084	135	76	1295	66.17%	197	76	389	662	33.83%
	Belgium		334	134	501	968	42.51%	1097	159	53	1309	57.49%
	France		57	24	12	94	30.52%	188	15	11	214	69.48%
	Other		262	80	143	485	76.26%	15	111	25	151	23.74%
	Total		2408	485	1172	4066	60.35%	1650	374	647	2671	39.65%
2001	Germany	Region Hamburg-Bremen	48	1	4	53	75.71%	9	1	7	17	24.29%
		Region Ruhr	307	67	434	808	65.37%	182	9	237	428	34.63%
		Region East Germany	26	13	0	39	70.91%	7	9	0	16	29.09%
	Netherlands		2167	150	401	2718	74.45%	256	114	563	933	25.55%
	Belgium		319	84	474	877	33.50%	1427	237	77	1741	66.50%
	France		56	6	13	75	20.95%	245	22	16	283	79.05%
	Other		26	128	72	227	50.44%	20	166	37	223	49.56%
	Total		2950	449	1399	4800	56.86%	2147	558	937	3642	43.14%
Source: Ontwikkeling Marktaandeelmodel Containersector, 2004												

4.3.2 Modal split

The quality of hinterland transport has become increasingly important for the competitiveness of a seaport. Shippers and carriers value the attractiveness of a port on not only the performance of the seaport, but also on its hinterland accessibility (Konings, 2006).

Generally, there are three main modalities in hinterland transportation, which are:

- Road
- Rail
- Inland waterway

The difference in choose modality will influence the transportation cost and transport time.

It has dramatic affection on port competition. In nowadays, the main battle field of port competition is in the hinterland parts. So, the difference in modal split must be considered in the port competition model.

4.3.3 Data requirements for the new model

This part will describe the data required for the model including the data needed for the improvements incorporated in the model. All required data concerns container transport.

Growing overall demand

- Data on actual (2005) throughput, capacity and utilization rate of different ports: Rotterdam and Antwerp;
- Actual (2005) total demand Rotterdam and Antwerp to determine market share in 2005;
- Forecast throughput volume Europe, Rotterdam and Antwerp for coming 30 years in container transport.

Demand specific port

- Port dues and terminal charges for Rotterdam and Antwerp;
- Service and dwell times for Rotterdam and Antwerp;
- Specific modeling of the transportation network for different transport modes, with data on transportation cost, distance and duration including dwell times at inland terminals;
- Data on route choice (performance total chain for transportation via specific port: value of time, congestion, reliability, out of pocket costs, scope possibilities)
- Data on shipper choice for a specific port (qualitative and quantitative)
- Data on route choice and shipper choice is probably very difficult to acquire. It depends on the available data in what detail this aspect will be incorporated in the port competition model. If availability is poor the assignment of traffic will be based purely on the generalized unit cost of the logistical chain and allocation of freight flows is determined using the discrete choice model.

Upgrading hinterland infrastructure

Forecast growth hinterland infrastructure in the destination areas.

TU Delft Delft University of Technology

5 Data for the model

In this chapter, all data that is necessary to build the model is described. First, the concept of generalized cost is explained. The cargo flow is analyzed and the port investment cost the port resident cost and hinterland transportation costs are constructed for the port competition model.

5.1 Generalized cost

As explained in the previous chapters, the shipping companies choose the logistic chain and the associated port mainly based on the utility for each chain. A main variable in this utility is the general transport cost for the different logistical chains. This cost includes all monetary cost of using a route but also non-monetary factors, such as the time required for the transport. The generalized cost for a transport chain consists of the following items:

Transport cost

- Sea transport costs
- Port of call costs
  - Port dues
  - Buoy dues
  - Quay dues
  - Towage
  - Pilotage
  - Mooring, unmooring
  - Vessel traffic service
  - Other dues (e.g. waste disposal dues)

- Container handling costs
  - Sea move, land move

- Hinterland transportation costs
  - Road, rail, inland waterway

Non-monetary factors that affect the generalized transport cost

- Transport time
- Availability of connection, frequency regarding the hinterland
- Quality and speed of container handling
- Reliability of transshipment (e.g. labor (strikes), ICT)

In this model, due to the two competition ports are geographically closed to each other, there will be only a small difference in the sea transport cost. So, that part of cost will be assumed equal for both competition ports. As a result, the total cost of the usage of port includes three main parts:

- Port investment cost
- Port congestion cost
- Hinterland transportation cost

In the following sections, detail data about these costs will be given.

5.2 Port investment cost

The port investment cost consists of port dues and terminal charges.

5.2.1 Port dues

It is generally known that port due is only a small part of the total transport costs for containers. This result from the fact that port dues are just a small portion of the total call costs (CRA, 2004).

In the short run, port authorities do not have the means to influence the quality of the basic service of providing port infrastructure such as quay walls, jetties and roads. Thus, a higher price does not reflect a better service provided by the port authority. This means that, higher pricing of a specific port would then be an indication of pricing power relative to rival ports.

In table 5-1, the port dues are showed.

Table 5-1 Port dues per container in 2003

	Port dues (Euro) Far east trade	Port dues (Euro) Transatlantic trade
Rotterdam	17	14
Antwerp	7	9

(Source: CRA, 2004)

It can be notice that, the overall price level at the port of Antwerp is considerably lower than in the port of Rotterdam but show a different pattern. Therefore, port dues do not seem cost-based but are used as a policy instrument/marketing tool.

5.2.2 Terminal charges

In this study, the terminal charges consist of all other (out of pocket) call costs but port dues. The main part of this terminal charges are container handling cost.
The terminal charges can be found in table 5-2.

Figure 5-2 Terminal charges per container in 2003

	Terminal charges (Euro) Far east trade	Terminal charges (Euro) Transatlantic trade
Rotterdam	11	16
Antwerp	9	14

(Source: CRA, 2004)

The most observation is that, terminal charges are higher for Rotterdam than for Antwerp. This can be explained by differences in quay productivity.

5.3 Port Congestion cost

The port congestion costs are time cost. To assign a monetary value to a time unit, the time unit has to be multiplied by VOT, which expresses the willingness to pay of a port user for a unit reduction of transportation time.
In table 5-3, the total VOT for containers is calculated.

Table 5-3 Total VOT for containers

Commodity group	Value (euro/TEU)	Mass (ton/TEU)	Value (euro/Ton)	VOT Commodity (euro/ton/day)
Consumer food	22,292	14.55	1532	0.58
Conditioned food	22,292	14.55	1532	0.58
Cement/manufactured building materials	765	14.65	52	0.02
Small machinery	198,508	10.85	18296	6.95
Miscellaneous manufactures	22,979	7.37	3118	1.18

(Source: W.A Gerrits, 2007)

Generally, if the congestion levels at the port are increases, the waiting time and time cost will increase as well.

The congestion cost can be calculated by the following expression:

$$t_n = t_{ff,n} \bullet \left(1 + c \bullet \left(\frac{Qn}{Kn}\right)^k\right)$$

The cost for service time is the production of service time and the VOT of containers in port. The cost is then:

$$OC^i(D_n) = VOT \bullet t_{ff,n} \bullet \left(1 + c \bullet \left(\frac{Qn}{Kn}\right)^k\right)$$

The parameter c and k are set at 0.45 and 4, the same as the model made in the previous study.

5.4 Hinterland transportation cost

The most important improve in the new model is that, a hinterland transportation network has been added in to the previous one. In this paragraph, more details will be further explains.

5.4.1 OD-Matrix

Due to the limitation of the data, only four regions, Stuttgart, Munich, Basel, and Milan, have been chosen as the hinterland destination areas.

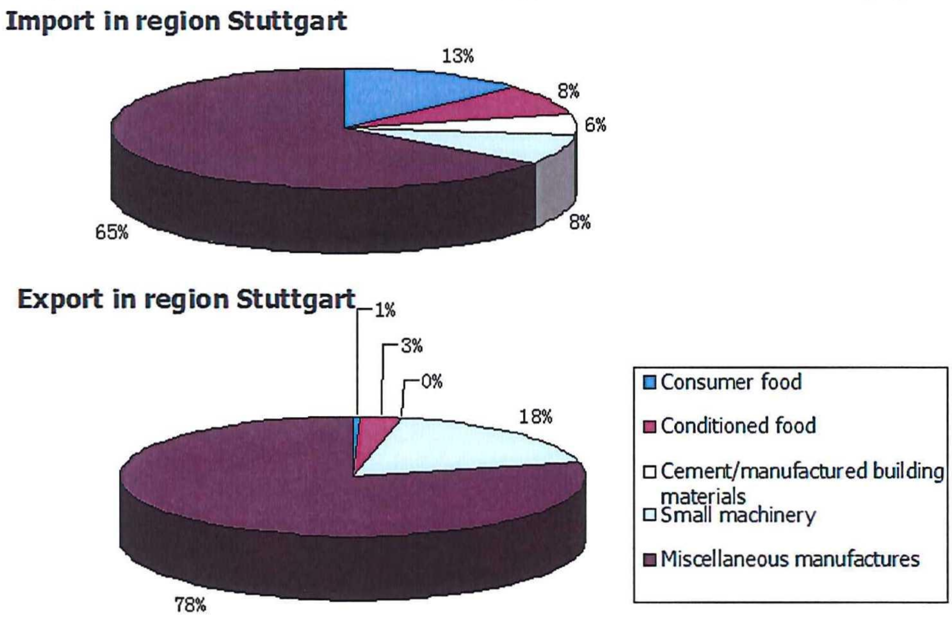
The OD-Matrix can be found in the table 5-4.

Table 5-4 O-D flows (in mln tonnes) with modal split (2005)

		Stuttgart	Munich	Basel	Milan	Total
Rotterdam	Truck	26.3	29.4	530.6	526.9	1113.3
	Barge	14.1	0	283.8	0	297.9
	Train	4.3	4.8	86.4	85.8	181.2
Antwerp	Truck	18.6	21.2	374.1	379.3	793.1
	Barge	10.2	0	206.1	0	216.3
	Train	2.2	2.6	45.8	46.4	97.1
Total		75.7	58.0	1526.7	1038.5	2699.0

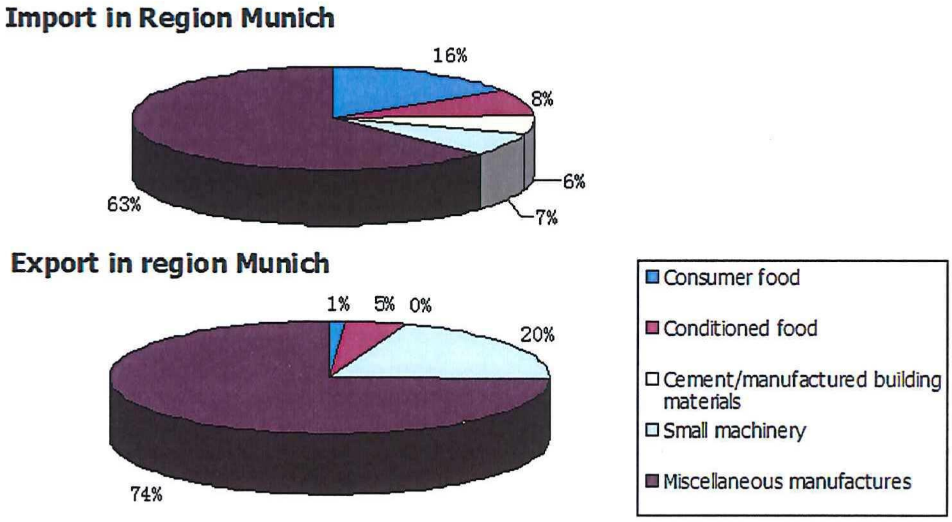
(Source: Dekker, 2005)

These four regions are all in the fighting area. And in total, it is about 30% in the yearly throughput. And for each region, the commodity type can be found in the following figures.



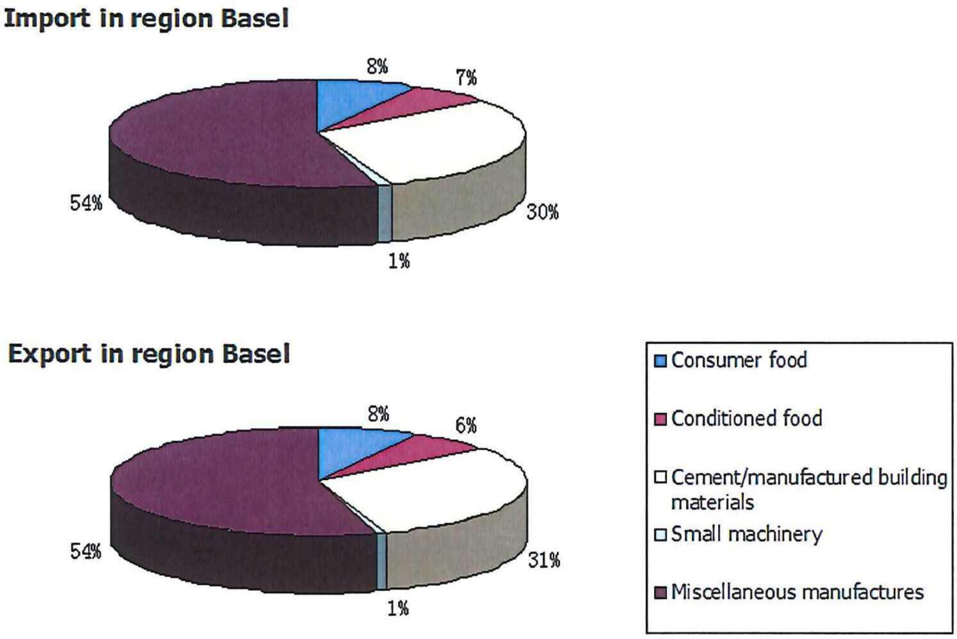
(Source: Dekker, 2005)

Figure 5-1 Container flows with commodity type in region Stuttgart



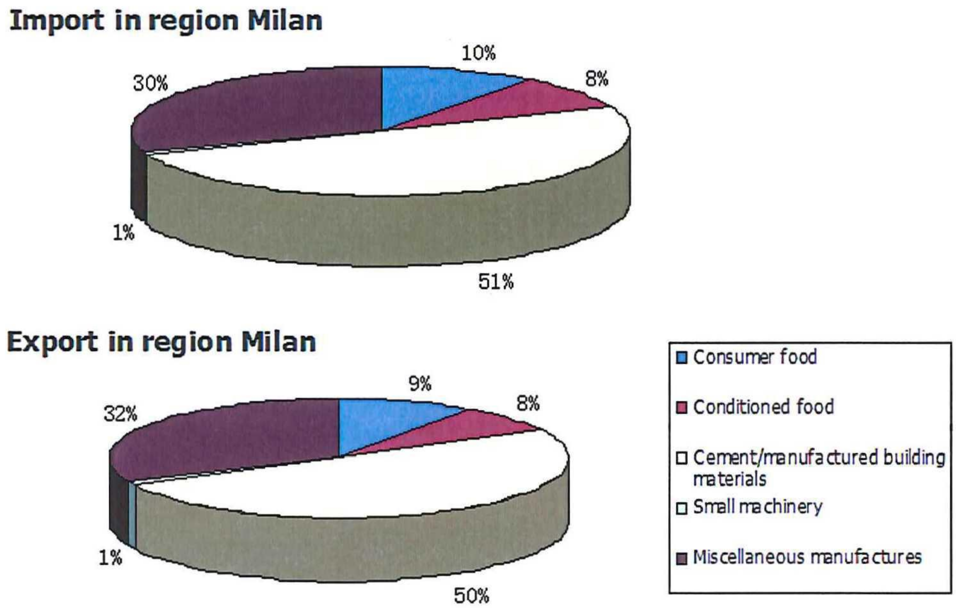
(Source: Dekker, 2005)

Figure 5-2 Container flows with commodity type in region Munich



(Source: Dekker, 2005)

Figure 5-3 Container flows with commodity type in region Basel



(Source: Dekker, 2005)

Table 5-4 Container flows with commodity type in region Milan

After knowing the OD-Matrix, and all the commodity type, it is possible to calculate the transportation cost in an aggregate level.

5.4.2 Other data

Except the OD-Matrix, other data such as distance between original and destination areas, the transportation cost for each modality, the transportation time and value of time are also gathered.

5.4.2.1 Distance

The distance between port and hinterland destination areas can be found in the table 5-5.

Table 5-5 The distance between port and hinterland destination areas in 2005

Truck(in km)	Stuttgart	Munich	Basel	Milan
Rotterdam	582	791	650	978
Antwerp	532	742	566	894
Train(in km)				
Rotterdam	648	890	773	1191
Antwerp	653	895	778	1264
Barge(in km)				
Rotterdam	745	0	762	0
Antwerp	918	0	852	0
"0" means there is no connection between original and destination areas.				

(Source: Dekker, 2005)

5.4.2.2 Cost

As show in the previous chapter, the transportation cost can be calculated with the following equation:

$$C_{nmr} = \sum_{j-1} p_t + \sum_{j} \beta_j \bullet I_{rj}$$

And it is assumed that, there will be no transshipment in the transportation. That is to say, no change of transport mode will be in the transportation. So, the $\sum_{j-1} P_t$ disappear in the equation. Then, the only parameters left to determine are the unit cost per ton per km β_j, and the transportation distance I_{rj}.

The unit cost per ton per kilometer is given in the table 5-6 for different transport modes.

Table 5-6 Transportation cost in 2003

	Size(TEU)	Transportation cost (Euro/ton*km)
Truck	2	0.08
Train	90	0.03
Barge	200	0.02

(Source: Dekker, 2005)

5.4.2.3 Time

The total number of days spent in the hinterland transit for route r is:

$$D_{nmr} = H_{ndj} + \sum_{j} \frac{I_{rj}}{24 \bullet S_j} + \sum_{j-1} H_{tdj}$$

It is also assumed that, cargo flows do not change mode at an inland terminal. The $\sum_{j-1} H_{tdj}$ disappears from the equation. The remaining parameters to determine are the dwell time in the port H_{ndj}, and the speed of hinterland transportation S_j, which are both determined by transport mode.

The dwell time for the different modes for port of Rotterdam and port of Antwerp is given in the table 5-7.

Table 5-7 The dwell time in the port

	Rotterdam	Antwerp
Import dwell vessel to truck	6.4	6.4
Import dwell vessel to train*	6.5	6.5
Import dwell vessel to barge*	4.1	4.1
*: For these modes of transport dwell times can easily be reduced by using inland terminals		

(Source: Dekker, 2005)

And average speed of hinterland transportation is given per mode in the table 5-8.

Table 5-8 Average transportation speed

	Size(TEU)	Average speed (Km/h)
Truck	2	50.0
Train	90	30.0
Barge	200	14.0

(Source: Dekker, 2005 and NEA)

Value of time can be found in the table 5-3.

5.4.3 Calculation hinterland transportation cost at an aggregate level

It is not workable for the competition model to calculate the transportation cost at a disaggregate level, due to the high number of connections. Now, it will explain how to calculate from the hinterland transportation cost at a disaggregate level to the hinterland transportation cost at an aggregate and workable level for the port competition model (As showed in the figure 5-5).

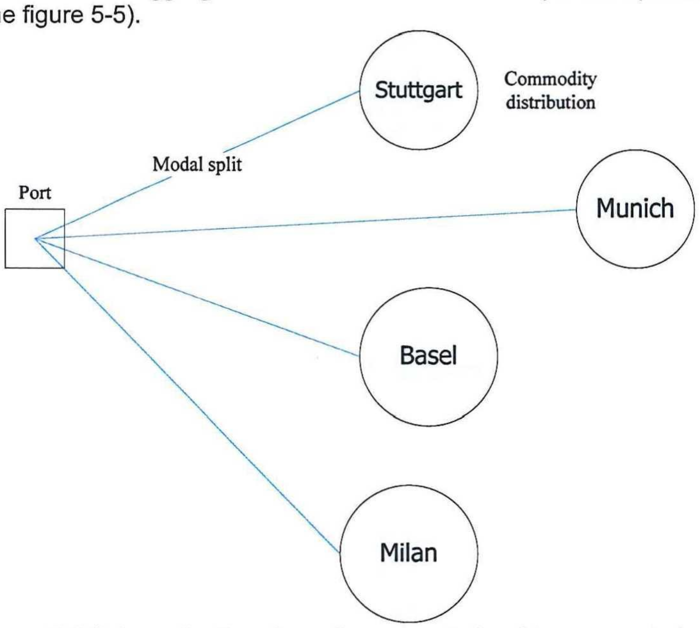


Figure 5-5 Schematization: from disaggregate level to aggregate level

A key assumption is that, the amount of transported TEUs of a specific cargo flow decide what the share is of this hinterland transportation cost at a disaggregate level in the hinterland transportation cost of a specific port to a specific region. First, the hinterland transportation cost are weighed for the amount TEUs of commodities transported, then these cost are weighed for the amount of TEUs transported per mode and finally these cost are weighed for the amount of TEUs transported to each region. As a result, the aggregate cost of transportation will be found.

The detail calculation steps can be found in the appendix 1.

6 Case study

The main task of this thesis is the use of the port competition model to develop the best strategy for the port expansion in a competitive environment. From the point of view of the port authority, the main objective for them is the largest market share. So, the strategy which can offer the largest market share will be the best strategy for port authority.
In order to do the case study, the port of Rotterdam and port of Antwerp, which are in the same area and highly compete with each other, will be chosen as a case study.

First of all, an analysis of each port will be given. The analysis includes the history, the geographical location, advantage, disadvantage, and also the expansion strategy for each port.

Then, these two ports will be put in the competition. The strategies will influence each other. In order to simulate for deciding on capacity expansion strategies, the important factors need to be indentified first. Based on the previous analysis, the main decisions in the port competition model are:

- Changing expansion plans;
- Hinterland upgrade infrastructure;
- Port congestion; and
- Global economy changes.

Then, in each assumption, the strategy will be compared by the port competition model.

Finally, a discussion will be given, which includes the limitation of model, the usage of game theory in the port competition and also the port planning.

6.1 Port of Rotterdam

The Netherlands are often called 'the gateway to Europe', and Rotterdam port, as the biggest port in the Netherlands, is the main port of the Netherlands, even in the European region. Rotterdam has been the largest European port for several years; in fact it was also the largest port in the world for a long time. In this chapter, the general back ground will be given, which includes the geographical location, historical overview, current situation and the future expansion planning.

6.1.1 Geographical location

The port of Rotterdam has an ideal location. Rotterdam is directly connected to the deep waters of the North Sea - the most heavily navigated sea route in the world. Major rivers such as the Rhine, Maas and the Schelde follow into the sea at Rotterdam. Rotterdam is situated in the heart of Europe.

Covering 105 square kilometers, the port of Rotterdam now stretches over a distance of 40 kilometers. It consists of the city center's historic harbor area, including Delfshaven; the Maashaven/Rijnhaven/Feijenoord complex; the harbours around Nieuw-Mathenesse; Waalhaven; Vondelingenplaat; Eemhaven; Botlek; Europoort, situated along the Calandkanaal, Nieuwe Waterweg and Scheur (the latter two being continuations of the

Nieuwe Maas); and the reclaimed Maasvlakte area, which projects into the North Sea.

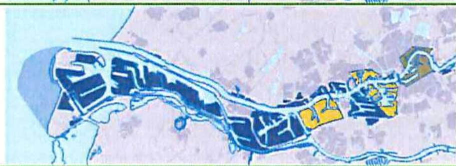
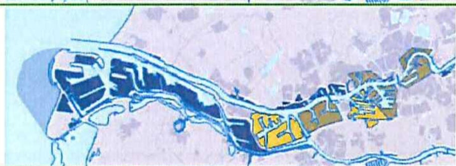
More than 500 scheduled liner services connect Rotterdam with over 1,000 ports worldwide. Many of the global container liner services only call at a limited number of European ports. Rotterdam is one of these, often as first and/or last port of call in Europe. From the port, feeder ships carry the containers by sea to smaller ports.

Figure 6-1 Port of Rotterdam

6.1.2 Historical overview

In the 14th century, Rotterdam was still a small fishing village situated on the river Rotte; six centuries later, it has become a world-class and the most important port for the continent of Europe. In the history, the port development could divide into six different time period. The reasons for those expansions are the same------the unbalance between capacity and demand.

Table 6-1 Six expansions in the history

Years	Name	Map
1400-1800	Haringhaven	
1800-1900	Industrial Revolution	
1920-1940	Waalhaven and Merwehaven, 1st Petroleum and 2nd Petroleum harbor	
1946-1960	Reconstruction	
1960-1970	Europoort	
1970-present	Maasvlakte	
Legend:	Existing port areas	Expansion areas

Source: Port of Rotterdam

6.1.3 Current situation

From 1962 until 2006 it was the world's busiest port, now overtaken by Asian ports like Singapore and Shanghai. In 2006, Rotterdam was world's seventh-largest container port in terms of twenty-foot equivalent units (TEU) handled.

6.1.3.1 Port statistics

Here are some key figures of this important port in 2006:

Table 6-2 Port area of Rotterdam

Area of industrial sites (available)	5,100 ha
Area of water	3,440 ha
Infrastructure	1,960 ha
Total Port length	40 km
Pipelines	1,500 km
Quay length	74 km
Slopes length	187 km
Total area	10,500 ha

(Source: Port Statistic)

Table 6-3 Tank storage of Rotterdam (x 1 million tons)

Crude oil (refinery storage)	12.0 m3
Crude oil (independent storage)	0.8 m3
Mineral oil products (refinery storage)	6.7 m3
Mineral oil products (independent storage)	5.0 m3
Chemical products (independent storage)	2.1 m3
Vegetable oils and fats (independent storage)	1.1 m3
Total	27.7 m3

(Source: Port Statistic)

Table 6-4 Cranes of Rotterdam

Container gantry cranes	92
Multi-purpose cranes	159
Bulk (gantry) cranes	58
Floating cranes	25
Sheer legs	10

(Source: Port Statistic)

Table 6-5 Terminals of Rotterdam

Container terminals (for deep-sea, short sea and inland shipping)	11
Multi purpose terminals	17
All Weather terminals	1
Roll on / Roll off terminals	7
Car terminals	1
Fruit terminals	2
Juice terminals	3
Bulk terminals	20
Cruise terminal	1

(Source: Port Statistic)

Table 6-6 Others

Tug boats	47
Pilot boats	6
Oil jetties	122
Buoy berths	23
Graven dry docks (of which covered 1)	6
Floating dry docks	7
Slipways	1

(Source: Port Statistic)

In 2008 almost 421.098 million tones (Source: Port of Rotterdam, Authority) of goods were transshipped in Rotterdam. According to the data in the past few years, we can find that, the amounts of goods are still increasing every year. And another important tendency we can find is that, the containers are playing a more and more important role in the total goods.

Table 6-7 Total goods throughput in the port of Rotterdam (millions of tones)

	2003	2004	2005	2006	2007	2008
Dry bulk(1)	85,986	89,254	89,446	87,806	90.642	94.935
Liquid bulk(2)	152,509	160,920	171,323	176,479	186.841	194.003
Containers	70,606	82,421	91,090	94,818	104.629	106.999
Other throughput	18,738	19,764	18,379	19.083	26.974	25.161
Total throughput	327,798	352,360	370,328	378,185	409.086	421.098
(1). Ores and scrap, coal, Agribulk, other dry bulk;						
(2). Crude oil, mineral oil products, other liquid bulk.						

(Source: Port Statistic)

Traditional, the most part of bulk of the cargo in the Port of Rotterdam is liquid bulk, especially, crude oil and mineral oil products. In 2006 this commodity group made up 46.66% of the total weight in goods. Dry bulk, such as ores and scrap are also key traditional cargos for the Port of Rotterdam. In 2006 these made up 23.22% of total weight. The share of containers in the total Rotterdam cargo shipment was over 25.07% in 2006. Container cargo mainly consists of piece goods such as toys, furniture and food products. Compared with year 2005, we can find that, the difference in dry bulk is -1.8%, in liquid bulk is 3%, and in container is 4.1%. So, in the near future, we can image that, the container will play a more and more important role in port of Rotterdam, even in the whole world shipment.

The transshipments of goods in the Port of Rotterdam grew by an average of 2.2 percent a year in the period 1998-2004. About 55 percent of the growth rate came from container shipping, which increased by an average of 5.8 percent a year. Transshipment of oil and oil products grew by an average of 1.8 percent a year. Ores and metal residues fell by an average of 0.3 percent a year.

And when we check the origin and destination of goods in Rotterdam's port, we can find another conclusion that, the import is far more then the export. The three main import areas are Europe, America, and Africa. And the three main export areas are Europe, Asia, and America.

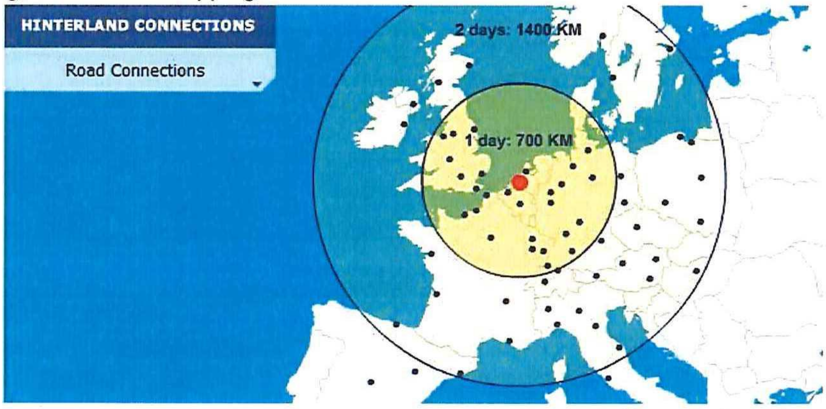
Table 6-8 Origin and destination of goods in Rotterdam's port to contains

Inbound	2001	2002	2003	2004
Europe	106,266	112,797	111,610	121,444
Africa	39,640	38,320	45,448	50,791
America	54,116	53,835	54,666	58,062
Asia	34,932	31,475	31,427	30,532
Oceania + other	10,642	10,763	10,947	10,311
Total inbound	245,596	247,190	254,098	271,140
Europe	38,433	39,526	39,840	44,784
Africa	2,339	2,458	2,876	2,378
America	10,120	11,570	11,337	12,022
Asia	16,219	19,402	18,049	21,514
Oceania + other	660	715	758	921
Total outbound	67,771	73,671	72,860	81,619

(Source: Port Statistic)

6.1.3.2 Hinterland connections

Rotterdam serves a hinterland of more than 150 million consumers living within a radius of 500 kilometers of Rotterdam, and 500 million consumers all over Europe. This is a gigantic market, representing a combined buying power of $ 600 billion. The European market is accessible from Rotterdam via four competing modalities: road, rail, inland shipping, and coastal shipping.



(Source: Port description)

Figure 6-2 Road connection of Rotterdam

(Source: Port description)

Figure 6-3 Railway connections of Rotterdam

(Source: Port description)

Figure 6-4 Inland waterway of Rotterdam

(Source: Port description)

Figure 6-5 Short Sea/ Feeder of Rotterdam

Goods which arrive in Rotterdam in a morning can be in, for example, Germany, Belgium, France or Great Britain the same afternoon. From Rotterdam, all major industrial and economic centers in Western Europe can be reached in less than 24 hours.

One of the main advantages of Rotterdam is its location on the estuary of the rivers Rhine and Maas. As a result, efficient and economical transport by inland vessel is possible deep into the heart of Europe. The Betuwe Route is the new, 160-kilometre long goods line that links Rotterdam directly with Germany. Feeder and short-sea ships connect Rotterdam by sea with more than 200 European ports; often with several departures a day. The short-sea/feeder ship is forming an increasingly important alternative to goods transport via Europe's busy roads. Underground, Rotterdam has direct links with the major industrial centers elsewhere in Northwest Europe. Pipeline is an ideal mode of transport for bulk chemicals, crude oil and oil products. Despite all this, the truck remains indispensable, particularly when it comes to more short-distance transport and door-to-door delivery.

6.1.4 Future expansion planning

As mentioned before, there will be more and more bulk and containers in the future. But the area of port of Rotterdam is very limited. And in this area, there are also other ports composite with Rotterdam.

Table 6-9 Container throughputs in major European ports

	2006	2005	2004	2003	2002
Rotterdam	9.690	9.288	8.292	7.144	6.506
Hamburg	8.862	8.088	7.003	6.138	5.374
Antwerp	7.018	6.488	6.063	5.445	4.777
Bremen	4.450	3.735	3.469	3.191	2.999
Algeciras	3.255	3.180	2.937	2.590	2.229

From the table 6-9, we can see that, Rotterdam is still the largest port in Europe. And it is also the largest container port in Europe. But the two main competitors, Hamburg and Antwerp are not really much smaller. But now, the port of Rotterdam has once again reached its limits in terms of possibilities for physical growth. There is hardly any plots in the existing port are available. And the new companies or existing customers wish to expand an additional space. If Rotterdam wants to carry on developing, then, the extra space must be created. The deep sea-related container sector, the chemical industry and distribution parks are in particular need of space. It is essential to find a new port area. So, the port authorities make the planning of Maasvlakte 2.

Maasvlakte 2 is the most important part of the Rotterdam Main port Development Project. This is a project that strengthens the main port. Maasvlakte 2 is the new port area and industrial zone that is to be built on the North Sea.

Here are some key factors of this project.

Table 6-10 General

Space for industrial sites	± 1000 hectares
Space needed for infrastructure	± 290 hectares
Space needed for sea defenses	± 230 hectares
Space needed for fairways and docks	± 510 hectares

(Source: Physical characteristics of Maasvlakte 2)

Table 6-11 Economic activities

Container storage and throughput	625 hectares
Chemicals (including innovative industry	210 hectares
Distribution	165 hectares

(Source: Physical characteristics of Maasvlakte 2)

Table 6-12 Infrastructures

Capacity for at least	16 million TEU
Roads	2 x 2-lane
Rail	Double, rail service centre

(Source: Physical characteristics of Maasvlakte 2)

Table 6-13 Access for Shipping

Length of navigation channel	ca. 10 nautical miles
Draught	tot 20 m
Width of Port entrance	> 600 m
Turning basin	1000 m

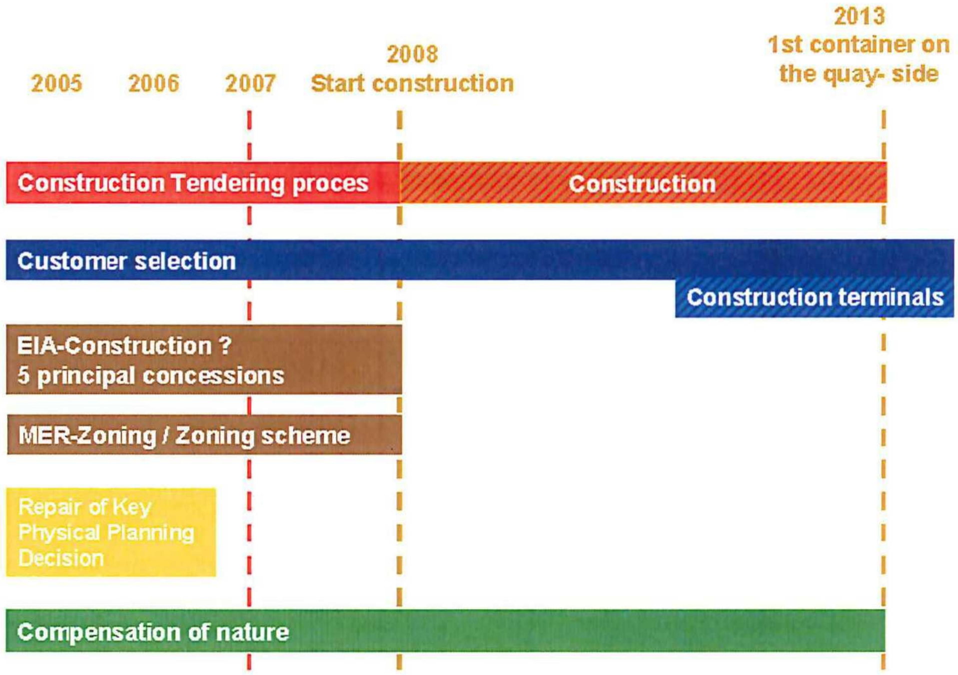
(Source: Physical characteristics of Maasvlakte 2)

With the construction of Maasvlakte 2, the current port and industrial area will increase by 20%, measured in hectares. As a result, the capacity to handle containers will treble. And at the same time, we also find that, the depth of Maasvlakte 2 is 20m. So, the container with 12 500TEU can use this new port.

The time schedule for Maasvlakte 2 is dependent on a number of procedures. The starting point is in January 2005.

The Maasvlakte 2 Project Organization is making sure that a contractor is selected in good time, to realize the port expansion. The application procedures for the necessary permits and the environmental impact assessment procedures for the Construction and Use are under way now. And the construction will begin in 2008.

Here, in figure 6-7 is the general project planning.



(Source: Planning Project Maasvlakte 2)

Figure 6-7 The general project planning of Maasvlakte II

With the development of Maasvlakte 2, a sustainable and high-quality industrial site will be created. This project will solve the future space shortage in the harbor of Rotterdam. In the next 20 to 30 years, there will be enough space for future growth. Already three terminal operators acquired contracts for new container terminals at Maasvlakte 2.

6.1.5 Containerization in Rotterdam

Rotterdam is the main port of European container transport. With an average of about 9.7 million TEU passing through the port each year, Rotterdam by far outstrips all the other ports in Europe.

Rotterdam owes its position as European container main port to a vast number of factors, such as:

- Excellent accessibility, also for the most recent generations of container ships;
- Nautical safety;
- Dedicated terminal facilities, both on the landside and the waterside;
- European transport hub function;
- Excellent hinterland connections, especially via inland vessel, short sea/feeder and rail; for more information click Transport
- Possibilities for expansion and setting up new operations;
- Fast turnaround times;
- Attractive location for bunkering, among other things as a result of competitive tariffs

The port has no draft limitations and can accommodate both current and future larger-scale container vessels, 24 hours a day and seven days a week. Many deep sea shipping lines opt for Rotterdam as their first and / or last port of call in Europe. And use it as their feedering hub for the UK, the Baltic and the Iberian Peninsula. Efficient interfaces with all important modalities ensure efficient hinterland transport.

The total container throughput in recent years can be found in table 6-14.

Table 6-14 Total container throughputs of Rotterdam in 2006 and 2007

		2006			2007		
		Empty	Load	Total	Empty	Load	Total
Incoming	Number containers	623.738	2.389.951	3.013.689	671.251	2.656.197	3.327.448
	Number TEU's	1.058.481	3.905.064	4.963.545	1.17.560	4.358.446	5.529.006
Outgoing	Number containers	576.028	2.256.716	2.832.744	725.183	2.435.440	3.160.623
	Number TEU's	948.843	3.740.844	4.689.687	1.217.231	4.044.367	5.261.598
Total	Number containers	1.199.766	4.646.667	5.846.433	1.396.434	5.091.637	6.488.071
	Number TEU's	2.007.324	7.645.908	9.653.232	2.387.791	8.402.813	10.790.604

(Source: port of Rotterdam authority)

The port is more than just a link in the logistics chain. As mentioned before, the European market is accessible from Rotterdam via all kinds of modalities: road, rail, inland shipping, coastal shipping and pipeline. For the hinterland container transportation, it mainly accomplished by road, rail and inland waterway. In the table 6-9, shows the modal split of containers in recent years.

Table 6-15 Modal split of containers Number of container moves *1000)

	2007(%)	2006(%)	2005(%)	2004(%)	2003(%)
Road	1471(30.4)	1364(30.5)	1246(30.5)	1188(31.3)	1102(31.3)
Rail	537(11.1)	486(10.9)	384(9.4)	358(9.6)	336(9.6)
Inland waterway	2835(58.5)	2619(58.6)	2458(60.1)	2332(59.1)	2079(59.1)
Total	4843	4469	4088	3878	3517

(Source: port of Rotterdam authority)

6.2 Port of Antwerp

The Port of Antwerp is a port accessible to container ships in the heart of Europe. It is one of Europe's largest sea ports, ranking third behind Rotterdam and Hamburg for container throughput in 2007. Its international rankings vary from 11th to 17th (AAPA). In 2007 the Port of Antwerp handled 182,900,000 Tons of trade and offered liner services to 800 different maritime destinations (Anne, Wittemans, 2008.)

6.2.1 Geographical location

Antwerp stands at the upper end of the tidal estuary of the Scheldt. The estuary is navigable by ships of more than 100,000 Gross Tons as far as 80 km inland. The inland location means that the port of Antwerp enjoys a more central location in Europe than the majority of North Sea ports. Antwerp's docks are connected to the hinterland by rail, waterway and road. It makes the containers could easily reach the industrial heartland via port of Antwerp.

Compared with port of Rotterdam, or other main ports in North-east Europe, there is a very significant disadvantage of Port of Antwerp. Due to the geographical location limitation, the container ships which want to arrival port of Antwerp need to pass the river Scheldt. So, here will become a bottleneck for the future development of Antwerp, as a result of keeping increasing in container ship size.

Figure 6-8 Port of Antwerp

6.2.2 Historical overview

The first evidence for the existence of the port of Antwerp dates from the 12th century, with Antwerp being mentioned sporadically as a point of embankment for passengers who travelling to England and Zeeland, and as an export port for wine from the Rhine and Mosel regions, destined for England. The port experienced its first period of prosperity from 1200 to 1350 thanks to the development of the textile industry.

In 1450 came the first expansion to the North, when the Sint-Pietersvliet dock was put into use.

The 16th century has gone down in history as Antwerp's Golden Age. The port expanded further, and in 1550 it had ten wharves spread over a distance of 2 km along the Scheldt, along with eight docks: Holenvliet, Sint-Jansvliet, Burchtgracht, Sint-Pietersvliet, Haringvliet, Boterrui, Brouwersvliet, Graanvliet and Timmervliet.

The first three decades of the 20th century brought huge expansion, both in terms of the freight volume and in terms of additional capacity in the polder areas to the North. The quays were extended, a third sea lock was built (Kruisschans lock), and additional docks were excavated (Leopold dock and Hansa dock).

An important step for the further development of the port of Antwerp was the setting up of

Antwerp Port Authority as an independent, municipally-owned company in 1997. Thanks to this independent status, the Port Authority is able to pursue its objectives in dealings with government and with market players all over the world. The present market trends, such as the increasing competition between ports and the trend towards concentration among shipping companies, demand continuous efforts in terms of cost control and services.

6.2.3 Current situation

The Port of Antwerp is the gateway to Europe, handling more than 180 million tonnes of freight annually (in 2007), with the figure rising each year. Antwerp is the second largest port in Europe for international shipping freight and the fourth largest in the world.

6.2.3.1 Port statistics

Statistics and key figures for the port of Antwerp can be found in the following tables.

Table 6-16 History of maritime cargo traffic (in tones)

Year	Unloaded	Loaded	Total
1995	65,111,622	42,961,778	108,073,400
1996	59,894,390	46,631,953	106,526,343
1997	63,065,530	48,829,253	111,894,783
1998	71,791,040	47,997,509	119,788,549
1999	66,149,708	49,504,312	115,654,020
2000	75,209,683	55,320,943	130,530,626
2001	74,227,441	55,822,972	130,050,413
2002	72,595,371	59,033,445	131,628,816
2003	77,596,356	65,278,156	142,874,512
2004	83,109,485	69,217,080	152,326,565
2005	87,077,092	72,977,273	160,054,365
2006	91,972,684	75,399,612	167,372,296
2007	99,829,214	83,067,574	182,896,788

(Source: port statistic of Antwerp)

Table 6-17 Maritime cargo traffic in 2007: overview (in tonnes)

		Unloaded	Loaded	Total
Overall traffic		99,829,214	83,067,574	182,896,788
general cargo		55,697,164	63,084,959	118,782,123
bulk cargo		44,132,050	19,982,615	64,114,665
Container traffic	T.E.U. (Twenty Feet Equivalent Units)	3,989,535	4,187,079	8,176,614

	goods tonnage	42,353,374	52,186,594	94,539,968
Ro/Ro traffic (excl. containers)		2,066,112	2,374,339	4,440,451

(Source: port statistic of Antwerp)

Table 6-18 Maritime cargo traffic in 2007: General cargo (in tonnes)

GENERAL CARGO	Unloaded	Loaded	Total
Iron and steel	6,504,512	5,739,483	12,243,995
Fertilizers and chemicals (bagged)	35,771	161,872	197,643
Wood	287,522	81,014	368,536
Cellulose and paper	2,446,907	474,674	2,921,581
Fruit	1,331,489	6,548	1,338,037
Granite	390,661	217,398	608,059
Flour	0	353,359	353,359
Sugar	0	42,171	42,171

(Source: port statistic of Antwerp)

Table 6-19 Maritime cargo traffic in 2007: Bulk cargo (in tonnes)

GENERAL CARGO	Unloaded	Loaded	Total
Crude oil	14,775,112	18,829	4,431,762
Petroleum derivatives	4,412,933	11,068,566	25,843,678
Chemicals	6,427,722	2,577,398	9,005,120
Ores	4,869,880	464,458	5,334,338
Coal	8,252,935	353,045	8,605,980
Cereals	591,642	457,003	1,048,645
Fertilizers	1,613,138	2,938,813	4,551,951
Sand and gravel	1,372,769	483,288	1,856,057

(Source: port statistic of Antwerp)

6.2.3.2 Hinterland transportation

Four transport modes offer efficient connections between the port and the European foreland and hinterland:

Road:
From Antwerp there are direct motorway connections to all the surrounding countries. Thanks to its inland location and the excellent connections, Antwerp is closer to the large centre of production and consumption than most of other ports.

Barge:
The Scheldt-Rhine connection and the Albert canal provide access to the hinterland. Numerous inland barge terminals in Belgium, the Netherlands, France and Germany offer very regular departures to and from Antwerp.

Barge transport has developed a great deal in the past few decades, and is now able to compete with road haulage even over short distances.

Rail:
All terminals in the port are connected with the European railway network. With a total of 1000 km railways and free capacity this modus will be the most important growth sectors for the future of rail transport, with heavy investments being made in equipment, rail infrastructure and terminals.

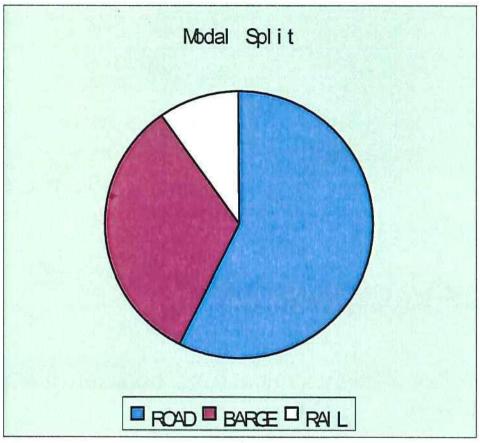
Short sea
When it comes to short sea and feeder connections, Antwerp aims to be a full-service partner. The port is constantly expanding its network of connections.

In table 6-17, the modal split of three main modalities of hinterland transportation can be found. And in figure 6-9, it shows the modal split in 2006.

Table 6-20 Modal split 1997-2006 (in 1.000 TEU)

	ROAD	BARGE	RAIL
1997	2,453	1,011	262
1998	2,805	1,202	338
1999	2,932	1,303	435
2000	3,148	1,523	523
2001	3,314	1,612	473
2002	3,316	1,742	520
2003	3,581	1,818	553
2004	3,808	2,034	499
2005	3,897	2,312	540
2006	4,111	2,377	700

(Source: port statistic of Antwerp)



(Source: port statistic of Antwerp)
Figure 6-9 Modal split of Antwerp in 2006

6.2.4 Future expansion planning

In implementation of the Flemish Government Agreement of July 1999, a planning process was started up in the Flemish ports, with each port area in Flanders having to draw up a land use plan with maximum protection for surrounding residential areas, maintenance and indeed extension of ecological infrastructure inside and outside the port area, and efficient use of space. The principles of the strategic plan form the basis for all further development within the port, whether it concerns shipping development or industrial development. The developments must also be accompanied by the creation or upgrading of ecological infrastructure in and around the port area.

In Antwerp, the strategic planning for the port areas on each bank of the Scheldt was originally carried out separately, but in the meantime the two planning processes have been combined, with a single, all-embracing strategic plan for the Antwerp port area being drawn up in 2006. The economic development study, the nature conservation background note and the Quick scan transport study have all been taken into account in the strategic plan.

The strategic plan for the port of Antwerp is aimed at developing the left and right banks of the Scheldt as a single, functionally integrated system with multiple uses. The core principle is that there should be economic development while maintaining the viability of villages within the area, and at the same time guaranteeing the conservation and development of nature assets. The strategic planning offers legal certainty for development of the port within a well-defined area.

Now that the boundaries of the port as a space for economic development have been defined, this should enable progress to be made in a number of projects that are considered to be of priority importance for the port and its development, thus safeguarding its future until 2030.

Priority projects that have been made possible include the second access to the Waasland port, completion of the Verrebroek dock, development of the Waasland Logistics Park and the Hoevenen Logistics Park, and a substantial increase in the container handling capacity.

6.2.5 Containerization in Antwerp

Three quarters of conventional/break-bulk freight is carried in containers. Antwerp plays a leading role here: maritime container handling in the port is growing at an annual rate of between 10% and 15%, and the port ranks 14th in the world for container freight.

One important advantage of the port of Antwerp is the presence of leading specialist container terminals, both on the Scheldt and in the docks. Large investments in infrastructure and the construction of a tidal dock with high-tech container terminals guarantee consolidation of the present market position and further development of the port. In 2007 the port of Antwerp handled 94.5 million tonnes of containers (more details can be found in table 6-18).

Table 6-21 Container traffic in 2007(mln TEUs)

	Unloaded	Loaded	Total
Europe	8.37	14.46	22.82
Near East	8.86	11.00	19.86
Middle & Far East	7.13	9.77	16.90
North & Central America	10.61	8.16	18.76
South America	3.28	3.32	6.60
Africa	4.02	4.62	8.64
Others	0.09	0.87	0.95
Total full + empty	42.35	52.19	94.54

(Source: port statistic of Antwerp)

The port actually lies some 80 km from the North Sea. This inland location offers a significant advantage for those seeking to control costs and serve the market efficiently: when the goods arrive in the port of Antwerp they are already closer to the customer, thus reducing the costs of onward transport by truck, train or barge.

The existing Delwaide dock on the right bank of the Scheldt has been fully renovated, following the setting up of the MSC Home Terminal on the South side of the dock. In 2008 the terminal has expanded with 440 meters at the north side of the Delwaide dock. With a quay length of 2.9 km the terminal is able to handle a large number of ships simultaneously, served by 21 ship-to-shore cranes and 124 straddle carriers.

The MSC Home Terminal for its part is able to handle 4.1 million TEU per year. The terminal, in which the freight handling company PSA HNN and Mediterranean Shipping Company (MSC) are partners, functions as the European hub for the MSC services. With more than 1400 calls per year MSC is by far the largest shipping line in the port of Antwerp.

Meanwhile the two container terminals on the Scheldt, the Noordzee terminal and the Europe terminal (both held by PSA HNN), are operating at full stretch. These are the two oldest tidal terminals in the port, having been in use since 1990 and 1996 respectively. Together they offer a container capacity of 3.7 million TEU.

These two terminals on the Scheldt were until recently the mainstays of container handling in Antwerp. With the renovation of the Delwaide dock and the expansion of the Deurganck dock, the port of Antwerp demonstrates that it is able to react flexibly and efficiently to the market demand for capacity.

6.3 Scenarios and assumption

In the following step, several scenarios will be made depending on the assumptions for the near future.

The assumption will include:
- Changing expansion plans;
- Changes in port congestion;
- Changes in hinterland congestion;
- Global economy;
- Combination strategies with uncertainty.

The basic situation including:
- Expansion plans: 5 mln TEU's per time.
- Port congestion: the utilization ratio is 90%
- Hinterland congestion
  - Modal split:

  Showed in table 6-22

Table 6-22 Modal split in 2005

	Rotterdam	Antwerp
Truck	0.43	0.49
Barge	0.23	0.27
Train	0.07	0.06
Transshipment	0.27	0.18

(Source: Dekker, 2005)

- Infrastructure growth:
  Rotterdam: Y=0.15X+b
  Antwerp: Y=0.1X+b
- Economy forecast: Y=9.5158+0.6706X

6.3.1 Changing expansion plans

In this assumption, the main focus is on the port strategy. The range of expansion will also influence the capacity expansion planning. The total cost of the expansion and the how many times of expansion are needed are determined by it.
Scenario 1: 3 mln TEU's per time;
Scenario 2: 5 mln TEU's per time; and
Scenario 3: 7 mln TEU's per time.

Other input data will keep the same as the basic situation.

6.3.2 Changes in port (or terminal) congestion

In this assumption, the port congestion will be more serious. And the more congestion in port means a longer dwell time. As a result for this, the service level will be lower and the total cost will be increasing. That will make port less attractive. So, how to deal with this congestion, and when to start the capacity expansion, is a significant issue for port authorities.

The utilization rate, defined as the ratio of actual flow through the port over capacity. The utilization rate forms the main input to determine port congestion. A new capacity expansion step is triggered when the utilization rate reaches a particular maximum threshold value.

The utilization rate is a control variable: it may be decided to lower congestion levels in order to attract a larger market share. So, in this assumption, the scenarios will be made based on the different utilization rate.
Scenario 1: 90%;
Scenario 2: 85%; and
Scenario 3: 80%.

Other input data will keep the same as the basic situation.

6.3.3 Changes in hinterland congestion

Under the general assumption that there is no difference in maritime transportation between Rotterdam and Antwerp, the main battlefield for those two ports is in the hinterland. So, how to connect the destination area with a high efficiency freight network is an important factor for both ports. In this assumption, modal split will be used to making the scenarios.
Scenario 1: mainly road;
Scenario 2: mainly railway; and
Scenario 3: mainly inland water way.

On other hand, the future hinterland infrastructure growths are also taken into account. The better hinterland connection means less transportation cost. Due to this reduction in total cost, the port will became more attractive for the shipping companies.
Scenario 1: Both change for the same rate
Rotterdam: Y=0.15X+1
Antwerp: Y=0.15X+1
Scenario 2: Rotterdam has a higher growth rate
Rotterdam: Y=0.2X+1
Antwerp: Y=0.1X+1
Scenario 3: Antwerp has a higher growth rate
Rotterdam: Y=0.1X+1
Antwerp: Y=0.2X+1

Other input data will keep the same as the basic situation.

6.3.4 Global economy

The changes in global economy will directly influence the total demand. The high growth in global economy means the high demand for container transportation. In the basic assumption, the forecast of the future demand increase following Y=9.5158+0.6706X.
Scenario 1: global economy boom: Y=9.5158+1X; and
Scenario 2: global economy crisis: Y=9.5158+0.447X.

Other input data will keep the same as the basic situation.

6.3.5 Combination strategies

In the previous section, some general scenarios are discussed. In those scenarios, the port expansion plan and the utilization rate can be fully decided by port authorities. But for the hinterland infrastructure, the national governments are the main decision maker. The port authorities only have a very limited power on it. And for global economy growth, it can be influenced by many factors, and with lots of uncertainty. So, it is quit important to take these two factors with uncertainty into account. By doing this, the port authorities could know that how to change their expansion plan and utilization ratio to deal with the uncertainty in the future.

Based on all the data and scenarios, the output of the model will be given in the chapter 7.

7 Output analysis

7.1 Introduction

In this chapter, all the output of the simulation will be given. In section 7.2, it is the output analysis of different expansion plans. In section 7.3, the main focus will be on different port congestion strategies. The analysis of different modal split and hinterland infrastructure growth will be given in section 7.4 and 7.5. The global economy forecasting will be considered in the section 7.6. The combination strategies will be analyzed in section 7.7.

7.2 Output analysis of different expansion plans

With different strategies of capacity expansion, different results of volume, utilization and market share of port of Rotterdam and port of Antwerp will be caused. In section 7.2, the outputs regarding these aspects at port of Rotterdam and port of Antwerp will be analyzed under the different scenarios of expansion strategies. The other simulation model parameters, including demand increase function (i.e. Y=9.5158+0.6706x), defined standard utilization rate (i.e. 0.9), modal split, hinterland infrastructure growth and social discount rate (i.e. 5%), are set fixed.

Three scenarios will be analyzed in the following chapter as mentioned in the section 6.3.1:

- Scenario 1: 3 mln TEU's per time;
- Scenario 2: 5 mln TEU's per time; and
- Scenario 3: 7 mln TEU's per time.

7.2.1 Detail output of the simulation

In the following chapter, the detail output of the simulation will be given. The main focus will be in four aspects:

- Capacity expansion for each port;
- Utilization for each port;
- Unit cost of each port, and
- Market share for each port.

7.2.1.1 Capacity expansion for each port

In the Figure 7-1, the capacity expansion of Rotterdam will be shown. An the capacity expansion of Antwerp will be illustrate in the Figure 7-2

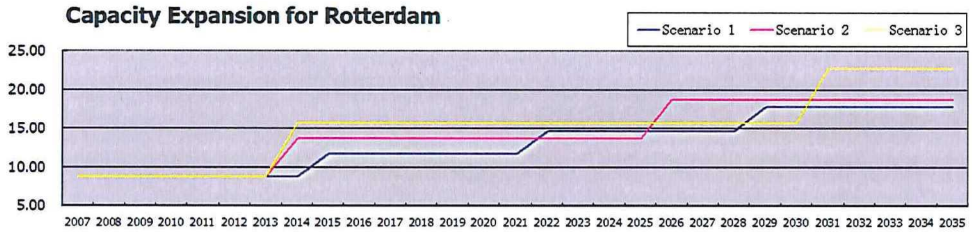


Figure 7-1 Capacity expansion of Rotterdam

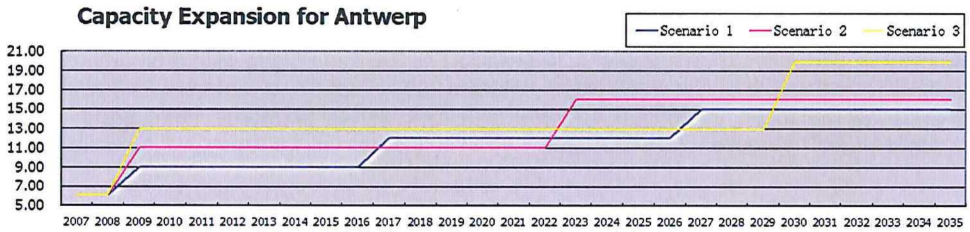


Figure 7-2 Capacity expansion of Antwerp

As can be found in the figure 7-1 and figure 7-2, in the scenario 1- 3 mln TEUs per time, both ports need to expansion three times. And in scenario 2 and scenario 3, only twice expansions are needed. At the same time, the total capacity after expansion will be lower, if the adding new capacity in per expansion time is smaller.

More detail data can be found in the Table 7-1.

Table 7-1 Capacity expansion data for two ports

		Number of Expansion	New capacity increase (mln TEUs)	Total expansion cost* (Euro/TEU)
Rotterdam	Scenario 1	3	9	995.34
	Scenario 2	2	10	1277.21
	Scenario 3	2	14	1499.40
Antwerp	Scenario 1	3	9	1413.26
	Scenario 2	2	10	1700.36
	Scenario 3	2	14	1996.38
*: The expansion cost only calculates till 2030.				

7.2.1.2 Utilization for each port

In the figure 7-3 and 7-4, the Utilization of each port will be given.

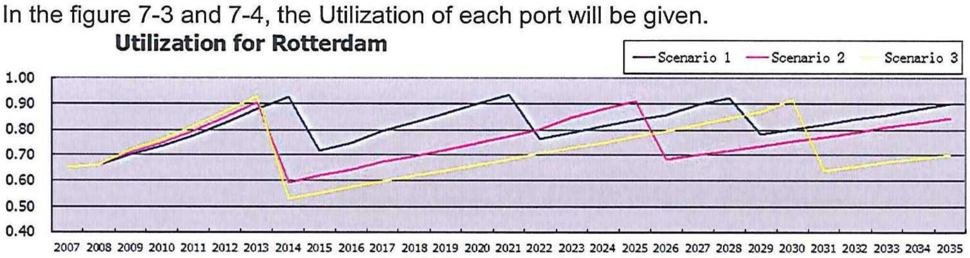


Figure 7-3 Utilization of Rotterdam

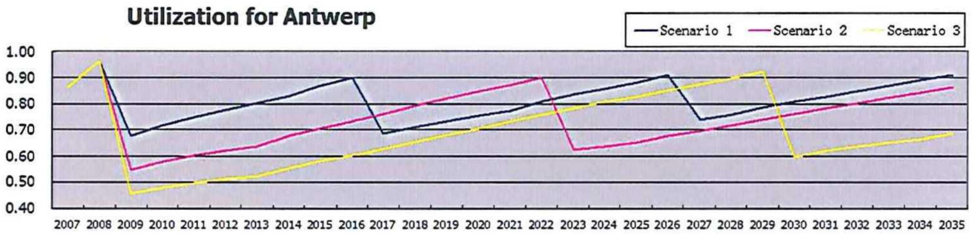


Figure 7-4 Utilization of Antwerp

As showed in these two figures, the utilization rate will drop dramatically after each expansion. And it will keep increasing till the next expansion. The average utilization will be higher in scenario 1 compared with the scenario 2 and scenario 3 in both port. In Rotterdam, the average utilization rate is 84% in scenario 1, 78% in scenario 2 and 74% in scenario 3. In Antwerp, the number is 83% in scenario 1, 76% in scenario 2 and 71% in scenario 3. And from the data mentioned above, it can be found that, the utilization rate in Rotterdam is higher then Antwerp.

7.2.1.3 Unit cost of each port

In the figure 7-5 and 7-6, the unit cost of each port will be shown.

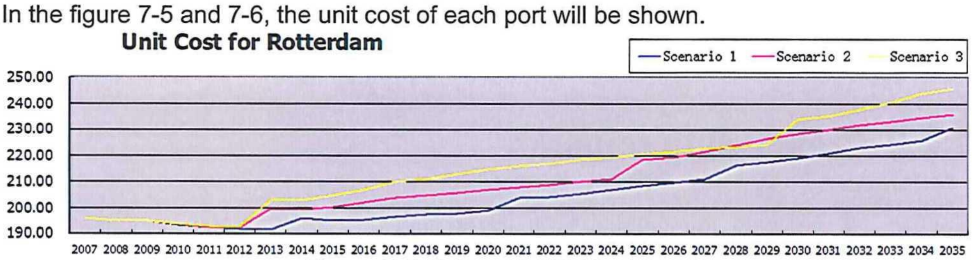


Figure 7-5 Unit cost of Rotterdam

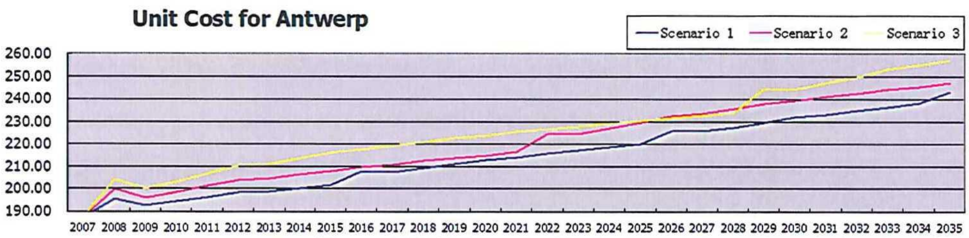


Figure 7-6 Unit cost of Antwerp

From figure 7-5, it can be found that, before the first expansion, the unit cost of Rotterdam is keep decrease in each scenario. And each expansion will make the total unit cost higher, due to the new investment recovery. And in figure 7-6, the port of Antwerp also shows the similar tendency.

7.2.1.4 Market share for each port

In figure 7-7 and figure 7-8, the market share of each port will be given.

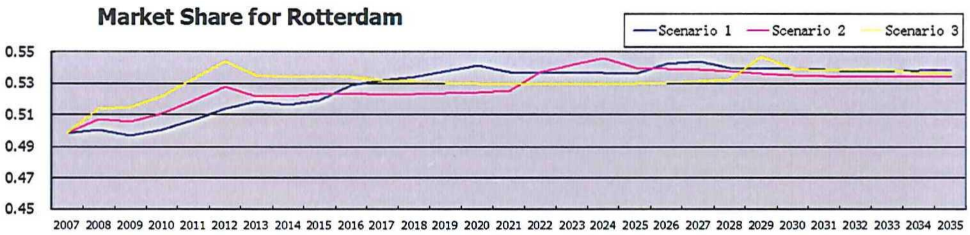


Figure 7-7 Market share of Rotterdam

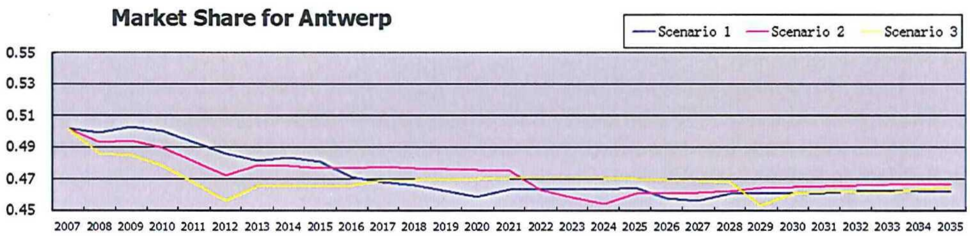


Figure 7-8 Market share of Antwerp

From these two figure, it can be found that, the market share of Rotterdam is always higher then Antwerp, due to the better hinterland connection (which will be further discussed in the section 7.4 and 7.5). And the market share will change in each time of capacity expansion. Because of as a result of expansion, new investment in port will make the unit cost larger.

7.2.2 Concluding remarks

Section 7-2 presents the outputs from the simulation model calculation under three different expansion strategies – 3 million TEU, 5 million TEU, and 7 million TEU per expansion. From the outputs analysis, several main concluding remarks are summarized as follows.

Same expansion plans for capacity expansion are concluded under scenario 1 (3 million TEU per expansion):
Port of Rotterdam need to expand capacity three times;
Port of Antwerp need to expand capacity three times.
Same expansion plans for capacity expansion are concluded under scenario 2 (5 million TEU per expansion), and scenario 3 (7 million TEU per expansion):
Port of Rotterdam need to expand capacity twice;
Port of Antwerp need to expand capacity twice.

Under all three scenarios, port utilizations increase quickly until the port utilization reaches the defined standard utilization rate, when the capacity expansion should be implemented. But the port utilization rate would drop dramatically when expansion is finished.

Market shares are the results of port utilization and expansion plans: cargo volume determines the port utilization and port utilization determine the port capacity expansion plan, which ultimately determine the market shares of ports.

7.3 Output analysis of different port congestions

With different port congestions, different results of volume, utilization and market share of port of Rotterdam and port of Antwerp will be caused. In section7.3, the outputs regarding these aspects at port of Rotterdam and port of Antwerp will be analyzed under the different defined standard utilization rate. The other simulation model parameters, including expansion strategy 5 mln TEU per time expansion, demand increase function (i.e. Y=9.5158+0.6706x), expansion strategy (i.e. 5 million TEU per expansion), modal split, hinterland infrastructure growth and social discount rate (i.e. 5%), are set fixed.

Three scenarios will be analyzed in the following chapter as mentioned in the section 6.3.1:

- Scenario 1: 90% utilization rate;
- Scenario 2: 85% utilization rate; and
- Scenario 3: 80% utilization rate.

7.3.1 Detail output of the simulation

In the following chapter, the detail output of the simulation will be given. The main focus will be in four aspects:

- Capacity expansion for each port;
- Utilization for each port;
- Unit cost of each port, and
- Market share for each port.

7.3.1.1 Capacity expansion for each port

In figure 7-9 and figure 7-10, the capacity expansion for each port will be illustrated.

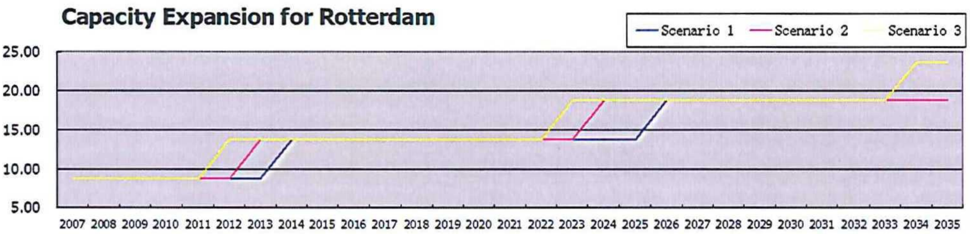


Figure 7-9 Capacity expansion of Rotterdam

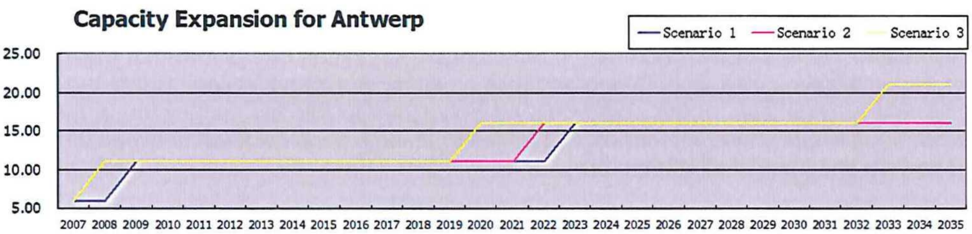


Figure 7-10 Capacity expansion of Antwerp

As can be seen in the figure 7-9 and figure 7-10, the capacity expansion time is directly determined by the utilization rate. If the utilization rate is low, then, the port needs to be expansion in an early time.

7.3.1.2 Utilization for each port

In the figure 7-11 and 7-12 the Utilization of each port will be given.

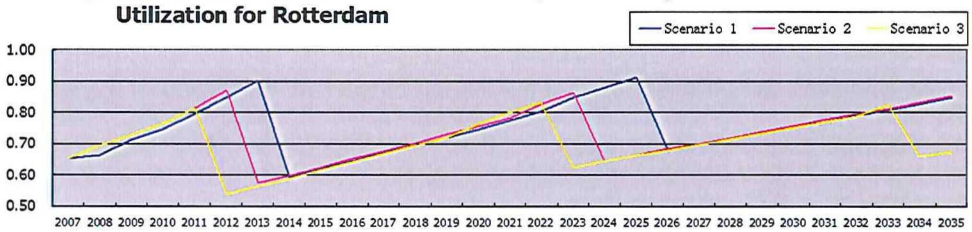


Figure 7-11 Utilization for Rotterdam

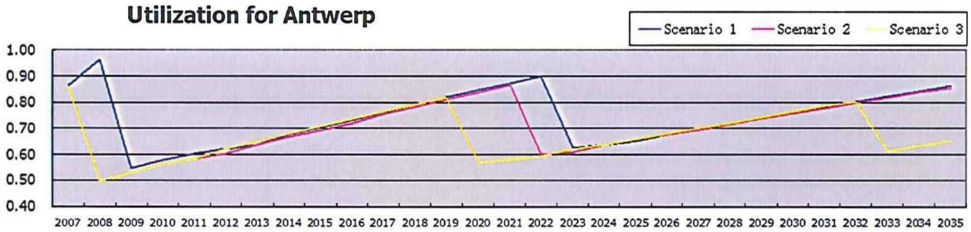


Figure 7-12 Utilization of Antwerp

The utilization rate in figure 7-11 an figure 7-12 shows the same tendency as figure 7-3 and figure 7-4. The utilization rate drops dramatically after each expansion. And it will keep increasing till the next expansion. More detail data can be found in the Table 7-2.

Table 7-2 Detail data for capacity expansion

		Standard Utilization	Average Utilization	Number of Expansion	New capacity increase (mln TEUs)	Total expansion cost* (Euro/TEU)
Rotterdam	Scenario 1	90%	78%	2	10	1277.21
	Scenario 2	85%	76%	2	10	1469.45
	Scenario 3	80%	72%	3	15	1694.79
Antwerp	Scenario 1	90%	76%	2	10	1700.36
	Scenario 2	85%	73%	2	10	1975.05
	Scenario 3	80%	70%	3	15	2186.77

*: The expansion cost only calculates till 2030.

From table 7-2, it can be found that, if the standard utilization rate is low, that means low average utilization rate for both port and also a high total expansion cost. But at the same time, the service level of the port would be better due to the low congestion in the port area. So, it is quit important for port authorities to make a good trade-off between the level of service and level of utilization rate.

7.3.1.3 Unit cost of each port

In the figure 7-13 and 7-14, the unit cost of each port will be shown.

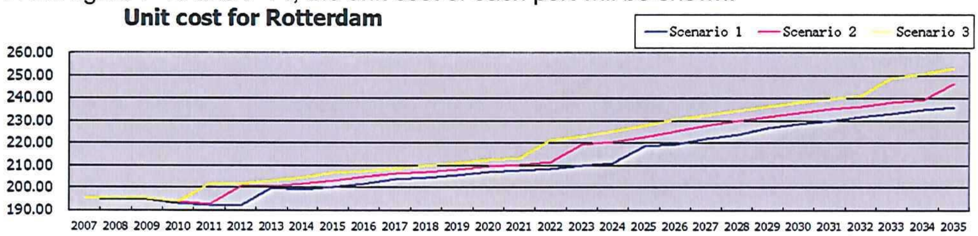


Figure 7-13 Unit cost of Rotterdam

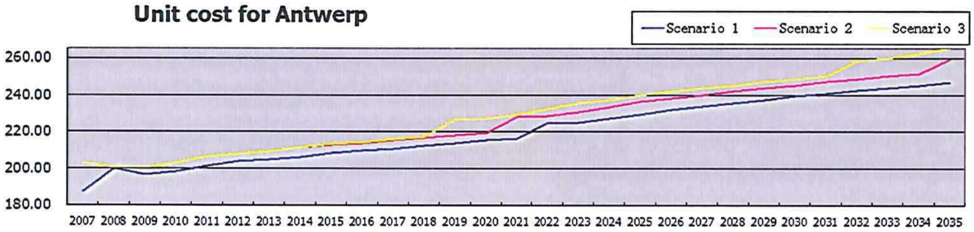


Figure 7-14 Unit cost of Antwerp

The tendency of the unit cost for both ports is the same as described in the section 7.2.1.3.

7.3.1.4 Market share of each port

In figure 7-15 and figure 7-16, the market share of each port will be given.

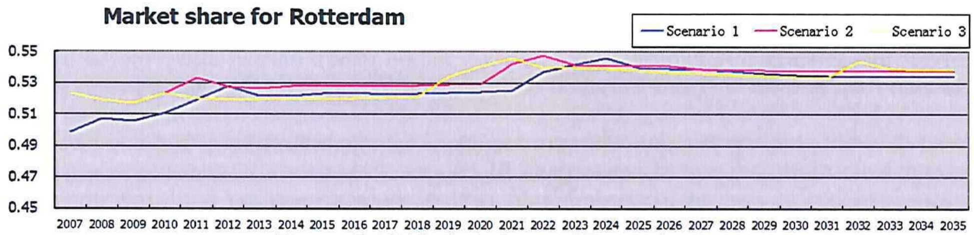


Figure 7-15 Market share of Rotterdam

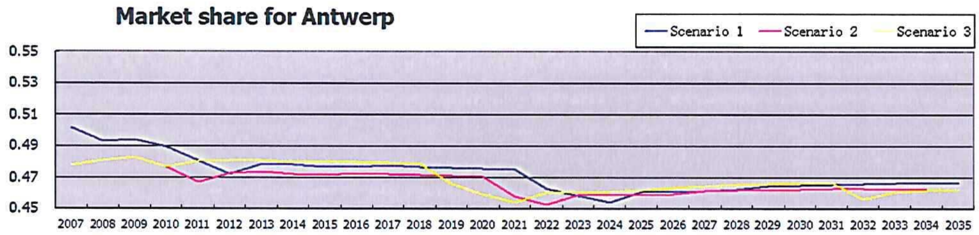


Figure 7-16 Market share of Antwerp

The market share of both port changes depends on the port expansion. The Rotterdam always in a better competition position compared with Antwerp.

7.3.2 Concluding remarks

Section 7-3 presents the outputs from the simulation model calculation under three different standard utilizations – 90%, 85%, and 80%. From the outputs analysis, several main concluding remarks are summarized as follows.

Same expansion plans for capacity expansion are concluded under scenario 1 (90%) and scenario 2 (85%):
Port of Rotterdam need to expand capacity twice;
Port of Antwerp need to expand capacity twice.
Expansion plans for capacity expansion are concluded under scenario 3 (80%):
Port of Rotterdam need to expand capacity three times;
Port of Antwerp need to expand capacity three times.

Under all three scenarios, port utilizations increase quickly until the port utilization reaches the defined standard utilization rate, when the capacity expansion should be implemented. But the port utilization rate would drop dramatically when expansion is finished.

A trade-off between the level of port service and level of standard port utilization rate needs to be made by port authorities.

Market shares are the results of port utilization and expansion plans: cargo volume determines the port utilization and port utilization determine the port capacity expansion plan, which ultimately determine the market shares of ports.

7.4 Output analysis of different hinterland congestions

Under this assumption, two different analyses will be given. One is about modal split (in section 7.4), and another one is based on hinterland infrastructure growth (in section 7.5)

With different port congestions, different results of volume, utilization and market share of port of Rotterdam and port of Antwerp will be caused. In section 7.4, the outputs regarding these aspects at port of Rotterdam and port of Antwerp will be analyzed under the different defined standard utilization rate. The other simulation model parameters, including expansion strategy 5 mln TEU per time expansion, demand increase function (i.e. Y=9.5158+0.6706x), expansion strategy (i.e. 5 million TEU per expansion), hinterland infrastructure growth and social discount rate (i.e. 5%), are set fixed.

Three different scenarios will be made:
- Scenario 1: mainly road transport;
- Scenario 2: mainly railway transport; and
- Scenario 3: mainly inland waterway transport.

7.4.1 Detail output of the simulations

The main output includes:

- Unit cost for each port;
- Hinterland transportation cost for each port; and
- Market share for each port

The other outputs, such as utilization, volume are more or less similar in the tendency as in the previous chapters.

7.4.1.1 Unit cost for each port

In the figure 7-17 and figure 7-18, the unit cost for each port under all scenarios will be given.

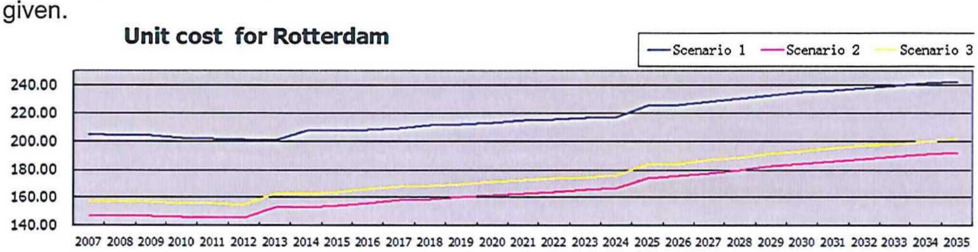


Figure 7-17 Unit cost of Rotterdam

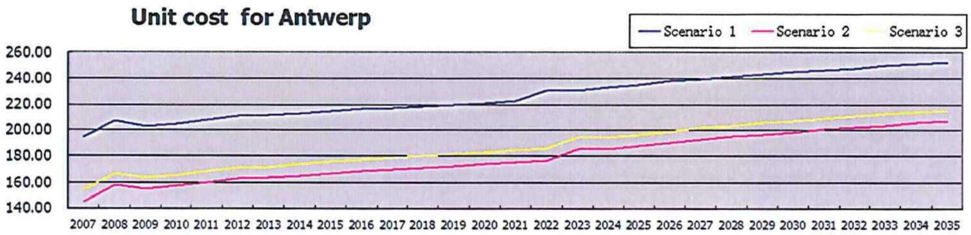


Figure 7-18 Unit cost of Antwerp

7.4.1.2 Hinterland transportation cost for each port

In the figure 7-19 and figure 7-20, the unit cost for each port under all scenarios will be given.

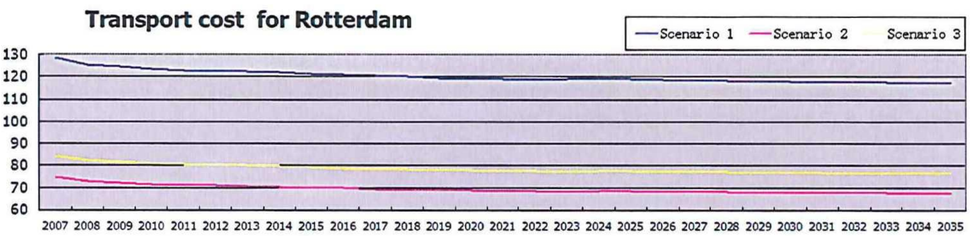


Figure 7-19 Hinterland transport cost of Rotterdam

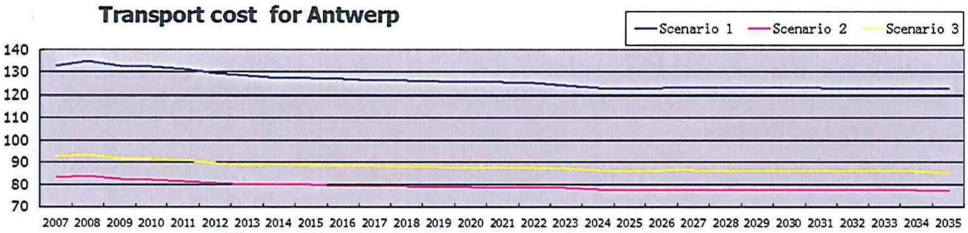


Figure 7-20 Hinterland transport cost of Antwerp

From figure 7-16 to figure 7-20, the unit cost and hinterland transport cost of each port is given. It can be found that, the hinterland transport cost is the main parts of total unit cost. It takes more than half of total cost. And it also can be seen, due to the hinterland infrastructure growth, the transportation cost is decreasing each year slightly. But the total unit cost is rising, as a result of port congestion and port investment recovery.

7.4.1.3 Market share for each port

In figure 7-21 and figure 7-22, the market share of each port will be given.

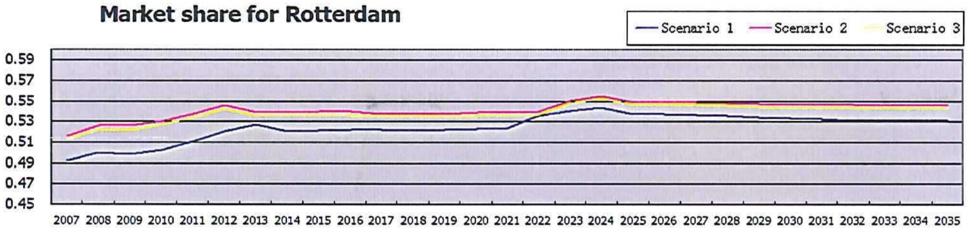


Figure 7-21 Market share of Rotterdam

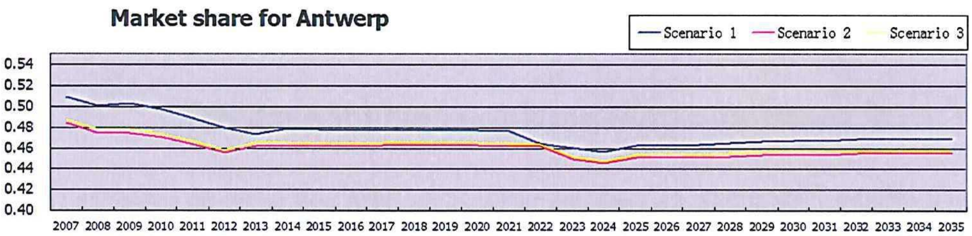


Figure 7-22 Market share of Antwerp

Figure 7-21 and figure 7-22 shows the market share of both port. From them, it can be found that under the scenario 2 (mainly railway) and scenario 3 (mainly inland waterway), the market share of Rotterdam is higher then scenario 1 (mainly road), that is to say, the port of Rotterdam has more advantages compared with Antwerp, if the hinterland transport is mainly finished by train or barge.

7.4.2 Concluding remarks

Section 7-4 presents the outputs from the simulation model calculation under three different main transportation modes – mainly road, mainly railway and mainly inland waterway. From the outputs analysis, several main concluding remarks are summarized as follows.

The transportation cost is the main part of the total unit cost (more then 50%). And it could influence the market share significantly. The port which has a better hinterland connection will take a better position in the competition.

General speaking, the inland waterway should be cheaper than the railway. But in this model, the railway is a little bit cheaper than the inland waterway. The reason for this is:

- Take the transportation time into account by using the value of time;
- The better hinterland railway connection in North-west part of Europe.

7.5 Detailed outputs from different hinterland infrastructure growth

With different strategies of capacity expansion, different results of volume, utilization and market share of port of Rotterdam and port of Antwerp will be caused. In section 7.5, the outputs regarding these aspects at port of Rotterdam and port of Antwerp will be analyzed under the different scenarios of hinterland infrastructure growth. The other simulation model parameters, including expansion strategy 5 mln TEU per time expansion, demand increase function (i.e. Y=9.5158+0.6706x), defined standard utilization rate (i.e. 0.9), modal split and discount rate (i.e. 5%), are set fixed.

Three scenarios will be tested in this chapter. A general assumption of those scenarios is that the growth rate in hinterland infrastructure is always higher then the growth rate of total volume. Other circumstances will be discussed in section 7.7.1.

Scenario 1: Both change for the same rate
Rotterdam: Y=0.15X+1
Antwerp: Y=0.15X+1

Scenario 2: Rotterdam has a higher growth rate
Rotterdam: Y=0.2X+1
Antwerp: Y=0.1X+1

Scenario 3: Antwerp has a higher growth rate
Rotterdam: Y=0.1X+1
Antwerp: Y=0.2X+1

7.5.1 Detail output of the simulation

The main output includes:

- Unit cost for each port;
- Hinterland transportation cost for each port; and
- Market share for each port

The other outputs, such as utilization, volume are more or less similar in the tendency as in the previous chapters.

7.5.1.1 Unit cost for each port

In figure 7-23 and figure 7-24, the unit cost of each port can be found.

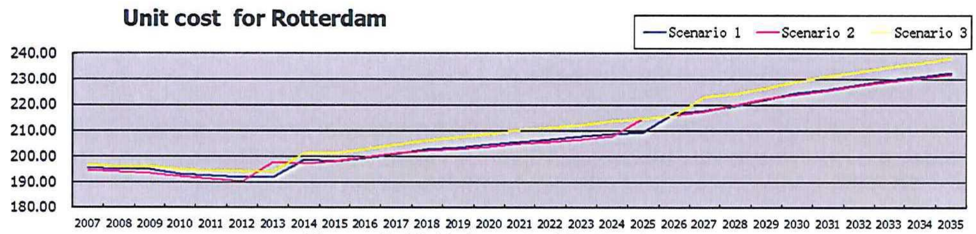


Figure 7-23 Unit cost of Rotterdam

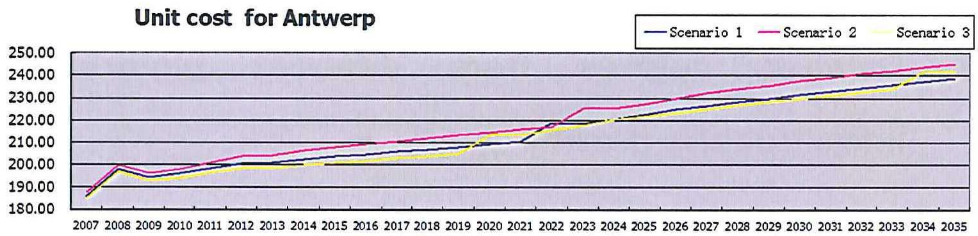


Figure 7-24 Unit cost of Antwerp

7.5.1.2 Hinterland transportation cost for each port

In figure 7-25 and figure 7-26, the hinterland transportation cost can be seen.

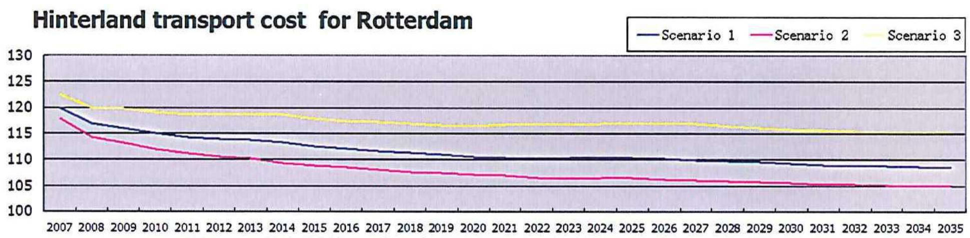


Figure 7-25 Hinterland transportation cost of Rotterdam

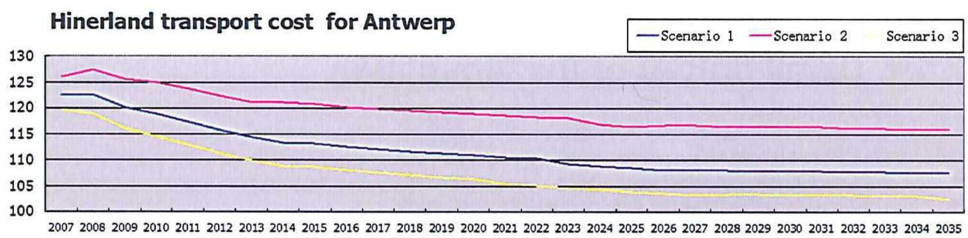


Figure 7-26 Hinterland transportation cost of Antwerp

In the figure 7-23 and figure 7-25, it can be found that, the unit cost and hinterland transportation cost in scenario 3 is higher than scenario 2 and scenario 1. The reason is that, in scenario 3, the hinterland infrastructure growth rate is lower than the other two scenarios. And the cheapest hinterland transportation cost is in scenario 2, which has the best hinterland infrastructure growth rate. The same trend can be found in the figure 7-24 and figure 7-26.

7.5.1.3 Market share for each port

The market share of each port under the different scenarios can be found in figure 7-27 and figure 7-28.

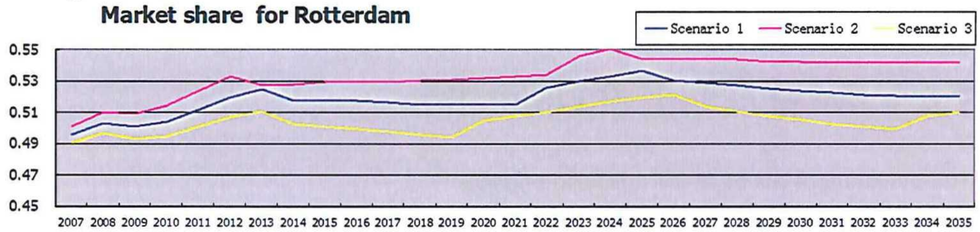


Figure 7-27 Market share of Rotterdam

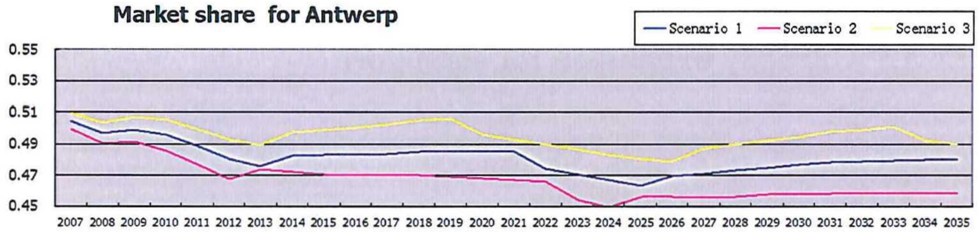


Figure 7-28 Market share of Antwerp

From figure 7-27 and figure 7-28, it can be seen that, the higher the hinterland infrastructure growth, the higher market share in ports.

7.5.2 Concluding remarks

Section 7-5 presents the outputs from the simulation model calculation under three different hinterland infrastructure growth rates – equal growth rate, higher growth rate in Rotterdam and higher growth rate in Antwerp. From the outputs analysis, several main concluding remarks are summarized as follows.

The transportation cost is the main part of the total unit cost (more then 50%). And it could influence the market share significantly. The port which has a better hinterland connection will take a better position in the competition.

7.6 Output analysis of different demand increase function

With different demand increase function, different results of volume, utilization and market share of port of Rotterdam and port of Antwerp will be caused. In section 7.6, the outputs regarding these aspects at port of Rotterdam and port of Antwerp will be analyzed under two different demand increase functions. The other simulation model parameters, including expansion strategy (i.e. 5 million TEU per expansion), defined standard utilization rate (i.e. 0.9), modal split, hinterland growth rate and social discount rate (i.e. 5%), are set fixed.

Two scenarios are made under an assumption that, the global economy will keep growing in coming 30 years:

- Scenario 1: global economy boom: Y=9.5158+1X; and
- Scenario 2: global economy crisis: Y=9.5158+0.447X.

7.6.1 Detail output of simulation

The main output will be in the following aspects:
Capacity expansion for each port;
Total volume for each port;

7.6.1.1 Capacity expansion for each port

In the figure 7-29 and figure 7-30, the capacity expansion for each port can be seen.

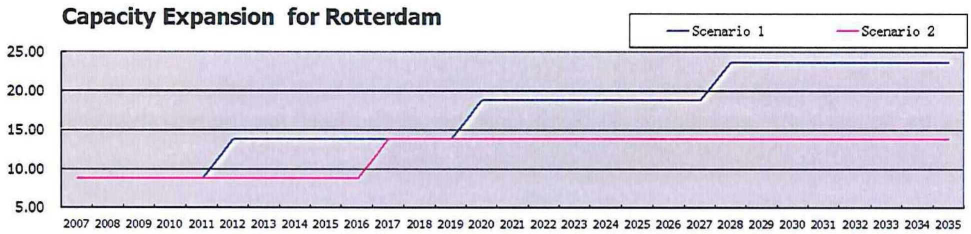


Figure 7-29 Capacity expansion of Rotterdam

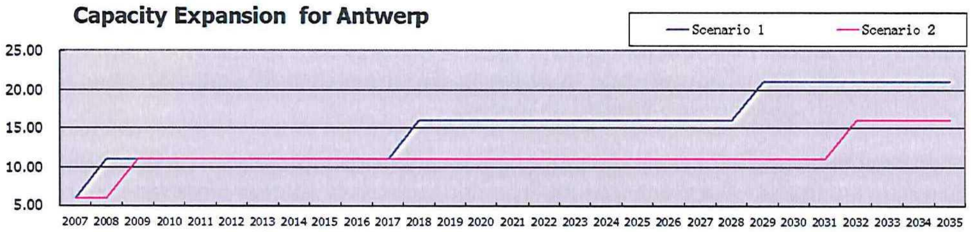


Figure 7-30 Capacity expansion of Antwerp

From the figure 7-29 and figure 7-30, it can be seen, under the global economy boom, both port need to be expanded three times. But for global economy crisis, the port of Rotterdam merely needs to expand once and the port of Antwerp only needs to expand twice. More detail data can be found in the table 7-3.

Table 7-3 Detail data for each port

		Number of Expansion	New capacity increase (mln TEUs)	Total expansion cost* (Euro/TEU)
Rotterdam	Scenario 1	3	15	835.83
	Scenario 2	1	5	1780.13
Antwerp	Scenario 1	3	15	1450.69
	Scenario 2	2	5	2206.66
*: The expansion cost only calculates till 2030.				

7.6.1.2 Total volume of each port

In the figure 7-31 and figure 7-32, the total volume of each port is given.

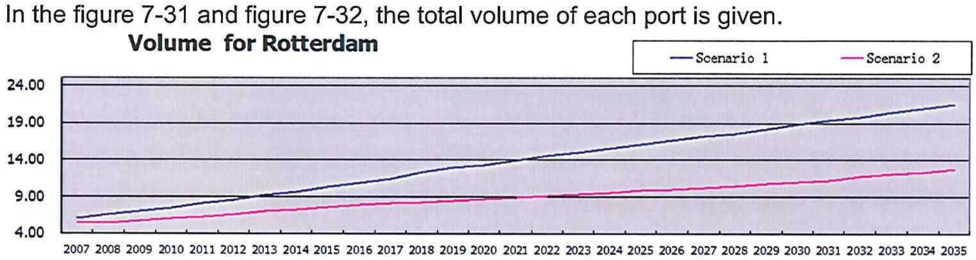


Figure 7-31 Volume of Rotterdam

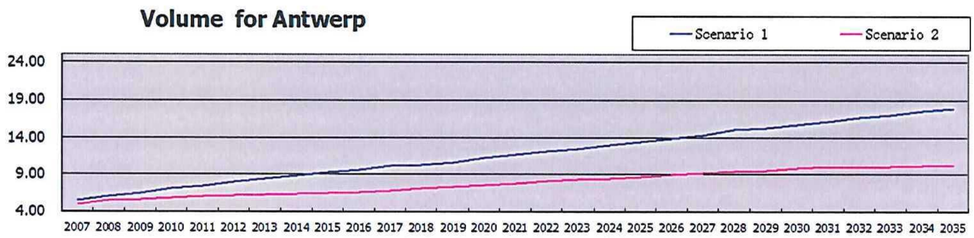


Figure 7-32 Volume of Antwerp

7.6.2 Concluding remarks

Section 7-6 presents the outputs from the simulation model calculation under two different global economy growth rates –global economy boom and global economy crisis. From the outputs analysis, several main concluding remarks are summarized as follows.

Under scenario 1 (global economy boom) the expansion plans for both ports:
Port of Rotterdam needs expanding three times;
Port of Antwerp needs expanding three times.

Under scenario 2 (global economy crisis) the expansion plans for both ports:
Port of Rotterdam needs expanding once;
Port of Antwerp needs expanding twice.

7.7 Combination strategies with uncertainty

As mentioned in previous chapters, port authorities can fully decide the port capacity expansion plan and port standard utilization rate. But they have very limited power on determine the hinterland infrastructure. And the same problem exists in the global economy growth. In this section, a discussion will be given considering the uncertainties in hinterland infrastructure and global economy.

7.7.1 Uncertain growth in hinterland infrastructure

The hinterland infrastructure will determine the hinterland transportation cost. It can influence the unit cost dramatically. And as a result, it can determine the market share of the port. In the 7.5, there is a discussion about the hinterland infrastructure under an assumption that the hinterland infrastructure growth rate is always higher than the growth rate of port volume. Hereby, some scenarios will be made to check, how the changes in hinterland infrastructure will influence the port capacity expansion if the hinterland infrastructure growth rate is lower or no growth.

7.7.1.1 No growth in hinterland infrastructure

In this scenario, there will be totally no growth in hinterland infrastructure in coming 30 years. The changes in unit cost of each port can be illustrated in figure 7-33.

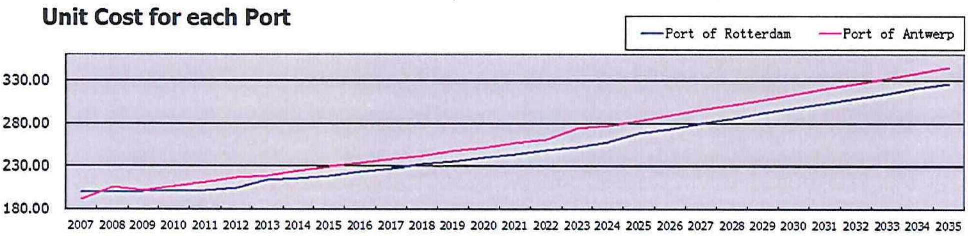


Figure 7-33 Unit cost of each port

Other data, such as the expansion plan, total volume for each port, utilization rate of each port and market share shows the same tendency as before. But the unit cost shows a significantly growth. As a result, the liners will choose other ports in the same region, which can offer a lower unit cost. The total volume of these two ports will decrease.

7.7.1.2 No growth in hinterland infrastructure in Rotterdam and higher growth in Antwerp

Under this scenario, there will be no growth in hinterland infrastructure in coming 30 years for port of Rotterdam. And for Antwerp, it will keep the same growth rate in basic assumption.

The expansion plan, total volume and market share can be found in figure 7-34, figure 7-35 and figure 7-36.

Figure 7-34 Expansion planning for each port

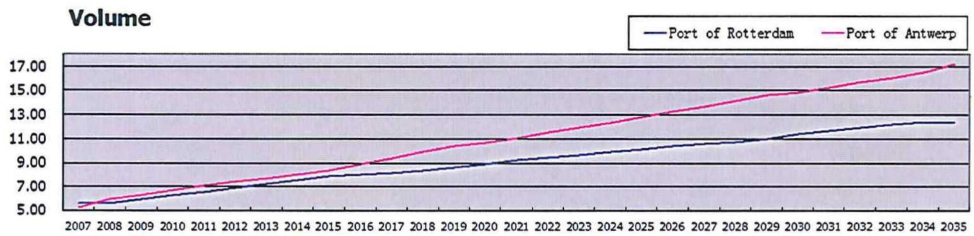


Figure 7-35 Volume for each port

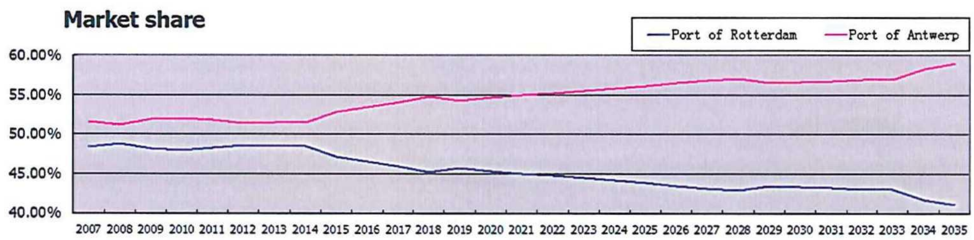


Figure 7-36 Market share of each port

From those figures, it is can be seen that, Antwerp need to expand three times to follow the capacity requirements. And it also has a higher total volume and market share. Those are all due to the better hinterland infrastructure. A high growth rate in hinterland connection means less congestion on hinterland transport. As a result, the unit cost will be lower (seeing figure 7-37), and more liner will choose the port of Antwerp.

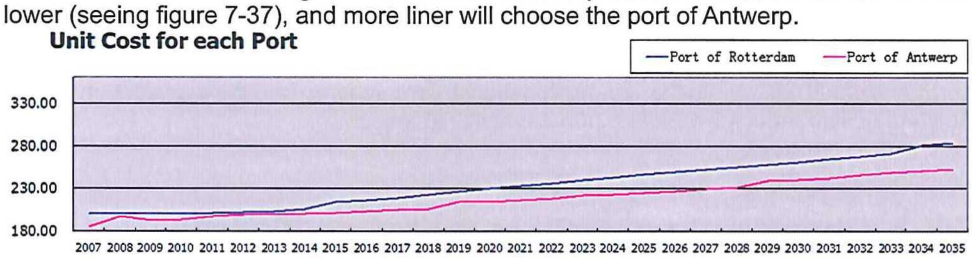


Figure 7-37 Unit costs for each port

7.7.1.3 The same growth rate at beginning and no growth after 2015 for port of Antwerp

In this scenario, the two ports will use the same growth rate at the beginning. And after 2015, the hinterland infrastructure will keep increasing. But the hinterland connection of Antwerp will keep the same. And after 2025, the hinterland connection will become even worse due to the lack of maintenances.

The expansion plan, total volume, and utilization can be found in figure 7-38, figure 7-39, and figure 7-40.

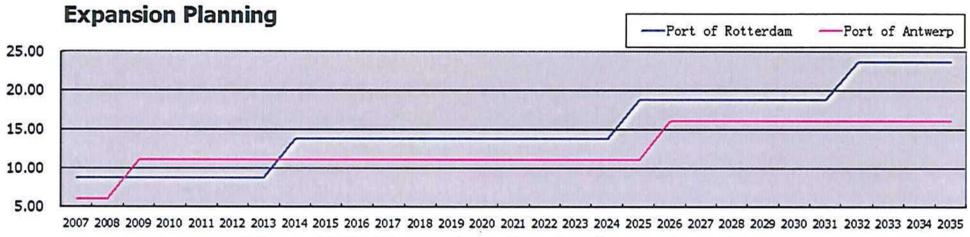


Figure 7-38 Expansion planning for each port

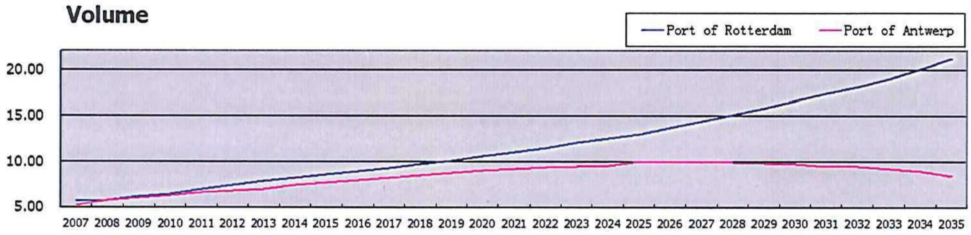


Figure 7-39 Volume for each port

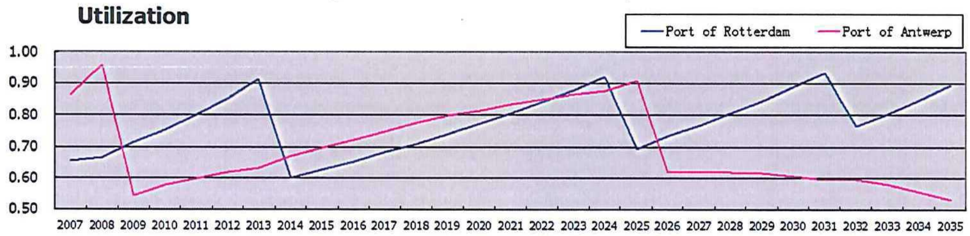


Figure 7-40 Utilization for each port

From figure 7-38, the port of Rotterdam needs to expand three times to supply enough capacity. And port of Antwerp only needs to expand twice. Form figure 7-39, it can be found the volume of Rotterdam keeps increasing. But the volume of Antwerp decreases from the year 2028, due to the serious hinterland connections. And the utilization in port of Antwerp is also reduced without a port capacity expansion.

7.7.2 Uncertainty growth in global economy

In section 7.6, the global economy growth has taken into account based on an assumption that the global economy will keep increasing in coming 30 years. In this section, further discussion will be given if the global economy stop increasing or even decrease one day.

7.7.2.1 No economy growth after 2015

In the figure 7-41 to figure 7-42, the expansion plan, total volume, utilization, and market share for both ports will be found.

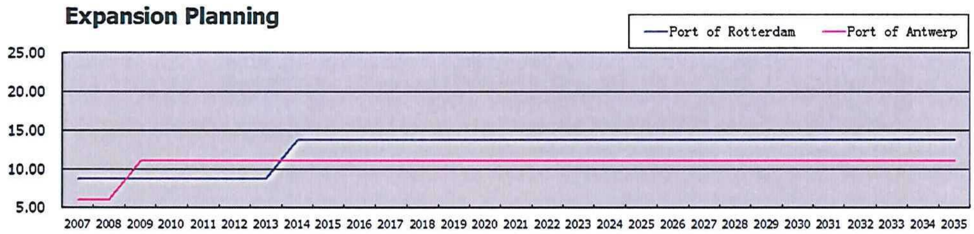


Figure 7-41 Expansion planning for each port

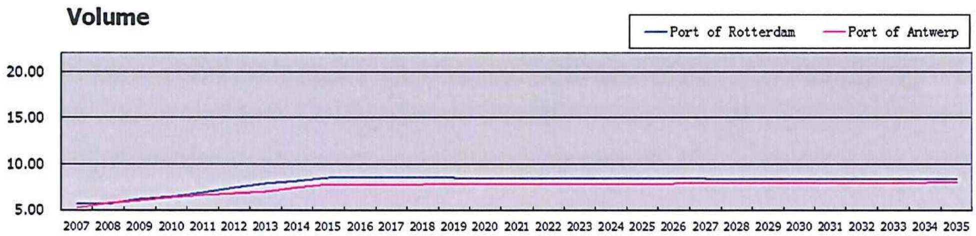


Figure 7-42 Volume for each port

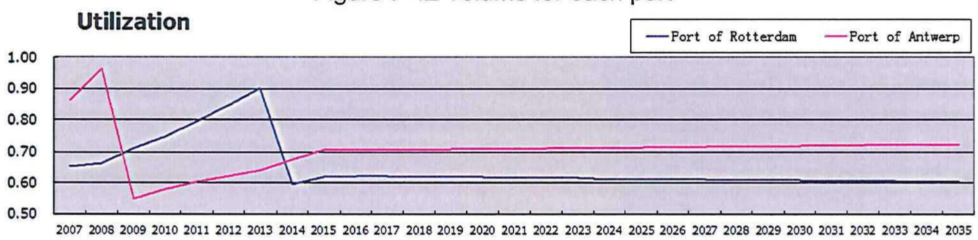


Figure 7-43 Utilization for each port

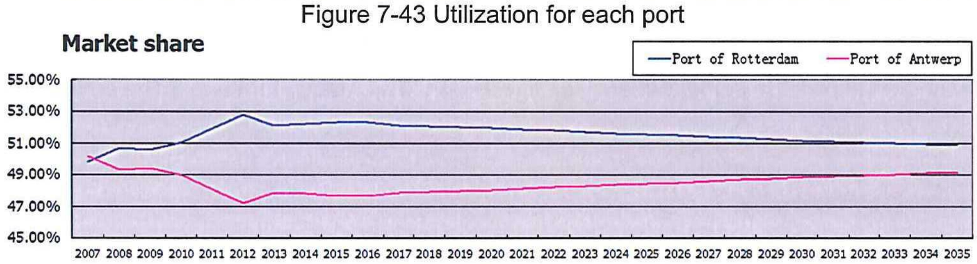


Figure 7-44 Market share for each port

From figure 7-41, it can be found that, if there is no further increase in the global economy, there is any need for any port capacity expansion. And the total volume and utilization will keep almost the same number. One interesting thing is that, the market share of Rotterdam is decreasing slightly after the 2015. The reason is that the keeping growths in hinterland infrastructure make the transportation cost lower. So, the share of port dwell cost will increase, which is higher in Rotterdam than Antwerp.

7.7.2.2 No economy growth after 2015 and decrease after 2025

In the figure 7-45 to figure 7-47, the total volume, utilization, and market share for both ports will be found.

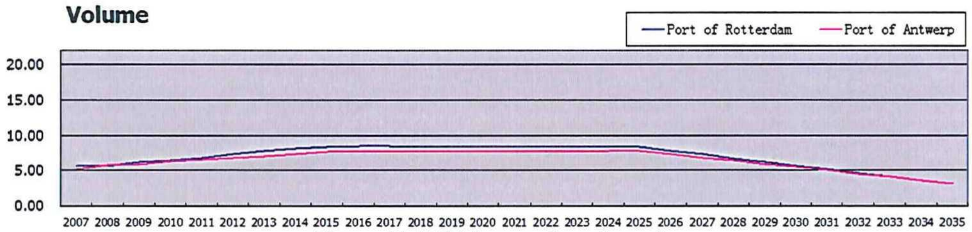


Figure 7-45 Volume of each port

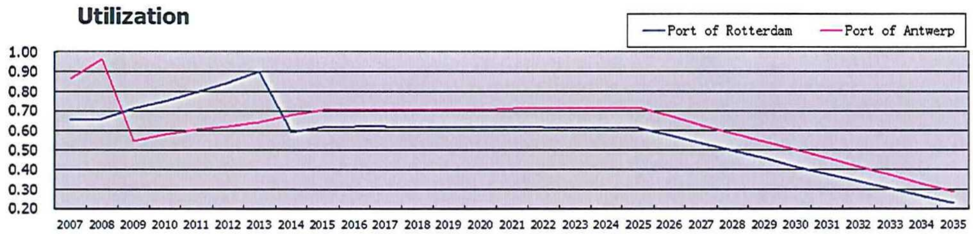


Figure 7-46 Utilization of each port

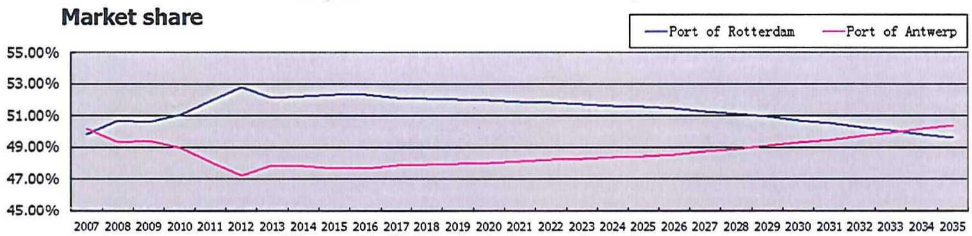


Figure 7-47 Market share of each port

In this scenario, the expansion planning is the same as the figure 7-41. The volume and the utilization decreases with the global economy decreasing. And the market share for each port shows the same tendency as figure 7-44. The reason for them is the same.

7.8 Summary

A case study has been given in Chapter 6 and Chapter 7. From this case study, it is can say that, the model which made in this study can use as an important tool to provide information to the port authorities when they deal with the port capacity expansion problem in a competitive environment.

As mentioned in the previous section, the main factors in planning of port capacity expansion include:

- Existing capacity;
- Expansion planning;
- Utilization;
- Hinterland transportation network;
- Hinterland infrastructure growth; and
- Total capacity demand.

All these factors can be test in the mode, and they influenced the final output-market share of each port, which is the main consideration of the port authorities in certain ways.

For port authorities, they can use this model to do a forecast of coming thirty years. By using it, they can get the effect of each decision they make, such as expansion plan, standard utilization. And also, they can use this model to simulation the hinterland infrastructure growth and global economy development, which they have very less power on. When take these uncertainties into account, the port authorities could make their decision more efficient and smart. They also can use this model to make trade-off between cost of port expansion and cost of port congestion. And also a trade-off between port service level and port utilization level can be made by the model.

Some logical results can get from the model:

- The port capacity plan can be determined by port investment cost, port service cost and hinterland transport cost. Except the hinterland transport cost, the port authorities have lots power on determine these factors. In the competition environment, the interaction of the strategies from each competition ports needs to be taken into account.

- It is not a good idea to add lots of new capacity once. In each expansion step, it is better to only increase small capacity which can make the utilization reaches an acceptable rate. That can reduce the total expansion cost and also always keep the utilization at a high rate.

- A trade-off between standard utilization rate and port service level need to be taken into account. A low standard of utilization rate means early expansion time, and it is also means more total expansion cost. But at the same time, the port service could keep at a high level, if the utilization level is low. Because that the ports always have enough capacity in a short time period of demand fluctuation.

- Hinterland transportation cost is the main parts of the total unit cost. Generally, rail transportation cost more Euro than inland waterway. But when consider the value of time an existing hinterland infrastructure. The railway could also be cheaper than inland waterway. The changes in hinterland transportation cost can dramatically influence the market share.

8 Conclusion and recommendation

In this chapter, the conclusion will be given in section 8.1. And in section 8.2, the main limitations of this study will be summed up, both in researching and model. Finally, recommendation and further studies will be showed in 8.3.

8.1 Conclusion

The research objective of this thesis is:

How can a simulation model be used to provide the best strategy for port authorities to deal with the port capacity expansion problem in a competitive environment?

The model is made in this study. It used a new concept that trade sea port as a node in the logistic chain in this new model. It can use as an important tool to provide information to the port authorities when they deal with the port capacity expansion problem in a competitive environment. Port authorities can use it to simulate the effect of hinterland transport, port congestion and port investment when they making the port capacity expansion planning.

The main attribution and conclusion of this study includes:

- A new concept which trade sea port as a node in the logistic chain is implemented in this thesis.
- A new model is made in this thesis. Compared with the existing transport model (SMILE & GSM), the model made in this study is not only containing the hinterland transport network, but also taking port development and the changes in market share into account.
- The inputs of the model are the factors which influence port competition and the outputs of the model are the key elements that the port authorities interested in.
- A combination strategy can be simulated to find the interaction of the uncertainties in the future.

To sum up, the model made in this study can be used as a tool to provide importations to port authorities to choose port capacity expansion strategies.

8.2 Limitations

Several limitations are in this study, which include research limitation and model limitation.

8.2.1 Research limitation

This study is restricted to competition within the container market. Other freights, such as general cargo and bulk cargo, are not included in this thesis. But, they will also influence the port competition to a certain extant.

In this study, only parts of the total throughput are taken into account. The focus is on the transit flows, which will be transported to the hinterlands destination. The part of transshipment flows is not included in the research.

Although there are many aspects that can improve port competition position, only capacity expansion strategies are considered.

There are still other ports in the Hamburg-Le Havre range, such as Hamburg, Bremen in Germany, Amsterdam in the Netherlands, Le Havre in France. Even other ports in France and Italy, will also compete with port of Rotterdam and Port of Antwerp. But in this study, only these two ports are considered.

The level of competition is restricted to inter-port competition. It is only from the perspective of port authorities.

8.2.2 Model limitation

The influences of overseas origins on cargo flows are not included in the modeling. In the model, the port is the "start point" of the network.

Only a small part of the market is modeled. The four destination regions, Munich, Stuttgart, Basel and Milan, only have less than 30% of the total throughput. And in these regions, merely import cargo flows are considered in the model.

It is assume that, the demand increasing ratio will be the same for both port and destination area. That is to say, if the total demand increased 10% for the port, then the destination area will also increase 10% equally.

There are some general assumptions in the model, such as it is assume that, there is no change in the mode at the inland terminal; there is only one route for each original-destination pair of OD-Matrix, and the distance is average number of the whole regions; the transportation cost for each modality is only determined by distance and time; rough estimates are made concerning the value of time, and the structure of port tariffs is left out of consideration.

No thorough investigation is done on the exact elements of the unit transportation cost per ton*km. it is only on an aggregate level of the whole regions.

Qualitative choice factors are not included in the model. The only factor that will influence the port choice is the cost.

8.3 Recommendation and further studies

Modeling at a disaggregate level gives more accurate result

The most important limitation in the model is that, all the transportation cost is calculated on an aggregate level. It is only an average cost depending on the modal split. In the real world, the transport cost will also be various depending on the destination area. So, if it can model at a disaggregate level, each route can be calculate separately, the output of the model will be more accurate.

Considering the historical data
Due to use logic model to determine the market share, and only use the total cost of the previous year, the changes of the market share are quit dramatic and sensitive, especially in the year when the expansion happens. The total cost will increase as a result of adding new port investment cost. If the market share can be determined not only by previous years, but also considering last five years or ten years, the out put will be more reliable.

Thorough analysis on port congestion and determination of congestion function
Port congestion level will directly influence the port service level. It can not be simply decided by the volume and capacity. More aspects need to be taken into account. And it can be improved by many methods besides capacity expansion.

Research on investment recovery
There will be different strategy to recover the port expansion investment for captive areas and fighting areas. Due to the limitation of data, all areas in the model are the fighting region. In the future research, the captive areas need to be put in the model. That will make the competition model more complete.

Expansion is not necessarily the best method to ease competition problems
Alternatives include:
Lower tariffs to reduce port-related costs
Fast cargo-handling facilities to reduce port service times
Cooperation between ports to develop competitive strategies together

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Appendix 1

Calculation transport cost at aggregate level

Input data:
Transportation cost in 2005

	Size(TEU)	Transportation cost (Euro/ton*km)
Truck	2	0.08
Train	90	0.03
Barge	200	0.02
Short sea vessel	500	0.01

Average transportation speed

	Size(TEU)	Average speed (Km/h)
Truck	2	50
Train	90	30
Barge	200	14
Short sea vessel	500	45.4

Distance (km)

	Stuttgart	Munich	Basel	Milan
Truck				
Rotterdam	582	791	650	978
Antwerp	532	742	566	894
Train				
Rotterdam	648	890	773	1191
Antwerp	653	895	778	1264
Barge				
Rotterdam	745	0	762	0
Antwerp	918	0	852	0
"0" means there is no connection between original and destination areas.				

Container Imports and Exports per Region in 2005 (TEU)
Region Stuttgart:

Commodity group	Import (TEU/year)	Export (TEU/year)	Mass (ton/TEU)	Value (euro/TEU)	share %
Consumer food	9988	221	15	22292	0.13
Conditioned food	5876	1053	15	22292	0.08
Cement/manufactured building materials	4597	0	15	765	0.06

Small machinery	5933	6928	11	198508	0.08
Miscellaneous manufactures	49346	31007	7	22979	0.65

Region Munich:

Commodity group	Import (TEU/year)	Export (TEU/year)	Mass (ton/TEU)	Value (euro/TEU)	share %
Consumer food	9260	308	15	22292	0.16
Conditioned food	4561	1390	15	22292	0.08
Cement/manufactured building materials	3525	0	15	765	0.06
Small machinery	4135	6140	11	198508	0.07
Miscellaneous manufactures	36559	22826	7	22979	0.63

Region Basel:

Commodity group	Import (TEU/year)	Export (TEU/year)	Mass (ton/TEU)	Value (euro/TEU)	share %
Consumer food	121271	115789	15	22292	0.08
Conditioned food	99577	96925	15	22292	0.07
Cement/manufactured building materials	455098	460102	15	765	0.30
Small machinery	14007	14089	11	198508	0.01
Miscellaneous manufactures	836794	820854	7	22979	0.55

Region Milan:

Commodity group	Import (TEU/year)	Export (TEU/year)	Mass (ton/TEU)	Value (euro/TEU)	share %
Consumer food	106185	100256	15	22292	0.10
Conditioned food	87736	81810	15	22292	0.08
Cement/manufactured building materials	523570	529559	15	765	0.50
Small machinery	6295	13131	11	198508	0.01
Miscellaneous manufactures	314719	334323	7	22979	0.30

Value of time:

Commodity group	Value (euro/TEU)	Mass (ton/TEU)	Value (euro/Ton)	VOT Commodity (euro/ton/day)	Value (euro/TEU)
Consumer food	22,292	14.55	1532	0.58	22292
Conditioned food	22,292	14.55	1532	0.58	22292
Cement/manufactured building materials	765	14.65	52	0.02	765
Small machinery	198,508	10.85	18296	6.95	198508

Miscellaneous manufactures	22,979	7.37	3118	1.18	22979

Modal split in 2005:

	Rotterdam	Antwerp
Truck	0.43	0.49
Barge	0.23	0.27
Train	0.07	0.06
Transshipment	0.27	0.18

Calculation steps:
Step 1: O-D flows with modal split (TEU)

		Stuttgart	Munich	Basel	Milan	Total
Rotterdam	Truck	26322.24384	29449.496	530596.87	526937.437	1113306.045
	Barge	14079.33973	0	283807.63	0	297886.967
	Train	4285.016438	4794.104	86376.23	85780.513	181235.8678
Antwerp	Truck	18556.3	21200.42909	374053.02	379337.5536	793147.2977
	Barge	10224.9	0	206110.85	0	216335.745
	Train	2272.2	2595.970909	45802.41	46449.49636	97120.07727
Total		75740	58040	1526747	1038505	2699032

Step 2: O-D flows with modal split and commodities (TEU)
To Stuttgart:

Port	Modality	Consumer food	Conditioned food	Cement/manufactured building materials	Small machinery	Miscellaneous manufactures	Total
Rotterdam	Truck	3471.172055	2042.111233	1597.61	2061.920685	17149.42493	26322.2
	Barge	1856.673425	1092.292055	854.54	1102.887808	9172.948219	14079.3
	Train	565.0745205	332.4367123	260.08	335.6615068	2791.766849	4285.02
Antwerp	Truck	2447.06	1439.62	1126.27	1453.585	12089.77	18556.3
	Barge	1348.38	793.26	620.60	800.955	6661.71	10224.9
	Train	299.64	176.28	137.91	177.99	1480.38	2272.2
Total		9988	5876	4597	5933	49346	75740

To Munich:

Port	Modality	Consumer food	Conditioned food	Cement/manufactured building materials	Small machinery	Miscellaneous manufactures	Total
Rotterdam	Truck	4698.524	2314.2514	1788.59	2098.099	18550.0366	29449.5
	Barge	0	0	0.00	0	0	0

	Train	764.876	376.7386	291.17	341.551	3019.7734	4794.1
Antwerp	Truck	3382.425455	1666.008909	1287.59	1510.402727	13354.00564	21200.4
	Barge	0	0	0.00	0	0	0
	Train	414.1745455	204.0010909	157.66	184.9472727	1635.184364	2595.97
Total		9260	4561	3525	4135	36559	58040

To Basel:

Port	Modality	Consumer food	Conditioned food	Cement/manufactured building materials	Small machinery	Miscellaneous manufactures	Total
Rotterdam	Truck	42145.82562	34606.41767	158162.14	4867.912192	290814.5723	530597
	Barge	22543.11603	18510.40945	84598.35	2603.766986	155551.9805	283808
	Train	6860.948356	5633.602877	25747.33	792.4508219	47341.90712	86376.2
Antwerp	Truck	29711.395	24396.365	111499.01	3431.715	205014.53	374053
	Barge	16371.585	13442.895	61438.23	1890.945	112967.19	206111
	Train	3638.13	2987.31	13652.94	420.21	25103.82	45802.4
Total		121271	99577	455098	14007	836794	1526747

To Milan:

Port	Modality	Consumer food	Conditioned food	Cement/manufactured building materials	Small machinery	Miscellaneous manufactures	Total
Rotterdam	Truck	53878.269	44517.2464	265659.42	3194.083	159688.4206	526937
	Barge	0	0	0	0	0	0
	Train	8770.881	7246.9936	43246.88	519.967	25995.7894	85780.5
Antwerp	Truck	38786.48455	32047.568	191245.84	2299.391818	114958.2675	379338
	Barge	0	0	0	0	0	0
	Train	4749.365455	3924.192	23417.86	281.5581818	14076.52255	46449.5
Total		106185	87736	523570	6295	314719	1038505

Step 3: Transportation cost (in Euro) (2005)

Port	Modality	Stuttgart	Munich	Basel	Milan	Total
	Truck	11751112.26	18206718.86	292756918.70	511308155.2	834022905
Rotterdam	Barge	2011461.167	0	45893182.09	0	47904643.25
	Train	798715.0147	1250564.4	21253680.95	38011628.71	61314589.08
	Truck	7572444.521	12294925.24	179712679.41	336471409.9	536051459.1
Antwerp	Barge	1800009.685	0	37265725.08	0	39065734.76
	Train	426799.6821	680071.5221	11343010.22	21844603.25	34294484.67

Step 4: Transportation time (day)

Port	Modality	Stuttgart	Munich	Basel	Milan
	Truck	0.49	0.66	0.54	0.82
Rotterdam	Barge	2.22	0.00	2.27	0.00
	Train	0.90	1.24	1.07	1.65
	Truck	0.44	0.62	0.54	0.82
Antwerp	Barge	2.73	0.00	2.54	0.00
	Train	0.91	1.24	1.08	1.76

Step 5: Total cost for time (Euro)

Port	Modality	Stuttgart	Munich	Basel	Milan	Total
	Truck	170536.0258	249982.0474	1944707.26	2068308.709	4433534.041
Rotterdam	Barge	417014.1342	0	4355090.65	0	4772104.784
	Train	51516.51702	76313.37799	627478.29	683386.8242	1438695.013
	Truck	109893.8182	168811.8879	1370953.46	1488956.963	3138616.131
Antwerp	Barge	373176.2227	0	3536377.376	0	3909553.599
	Train	27528.25812	41555.26698	334882.82	392730.1867	796696.5355

Step 6: Total Transportation cost (Including VOT) (Euro)

Port	Modality	Stuttgart	Munich	Basel	Milan	Total cost
	Truck	11921648.29	18456700.91	294701626	513376463.9	
Rotterdam	Barge	2428475.301	0	50248272.74	0	953886471.2
	Train	850231.5318	1326877.778	21881159.25	38695015.53	
	Truck	7682338.339	12463737.13	181083632.9	337960366.9	
Antwerp	Barge	2173185.908	0	40802102.45	0	617256544.8
	Train	454327.9402	721626.789	11677893.04	22237333.43	

Step 7: Aggregate transportation cost (Euro/TEU)

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Appendix 2

Table 1-3mln TEU per expansion time

Year	Rotterdam					Antwerp					Total volume
	Volume mlnTEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	Volume mln TEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	
2005	6.10	8.70	201.65	0.70	0.59	4.20	6.00	185.43	0.70	0.41	9.52
2006	6.03	8.70	198.10	0.69	0.52	4.15	6.00	182.96	0.69	0.48	10.19
2007	5.67	8.70	195.60	0.65	0.50	5.18	6.00	187.34	0.86	0.50	10.86
2008	5.75	8.70	194.86	0.66	0.50	5.78	6.00	195.70	0.96	0.50	11.53
2009	6.11	8.70	194.75	0.70	0.50	6.09	9.00	192.66	0.68	0.50	12.20
2010	6.40	8.70	193.24	0.74	0.50	6.47	9.00	194.28	0.72	0.50	12.87
2011	6.77	8.70	192.29	0.78	0.51	6.77	9.00	196.57	0.75	0.49	13.54
2012	7.20	8.70	191.78	0.83	0.51	7.01	9.00	198.39	0.78	0.49	14.21
2013	7.64	8.70	191.38	0.88	0.52	7.24	9.00	198.91	0.80	0.48	14.88
2014	8.06	8.70	195.50	0.93	0.52	7.49	9.00	200.24	0.83	0.48	15.55
2015	8.38	11.70	194.81	0.72	0.52	7.84	9.00	201.81	0.87	0.48	16.22
2016	8.77	11.70	195.36	0.75	0.53	8.12	9.00	207.73	0.90	0.47	16.89
2017	9.29	11.70	196.27	0.79	0.53	8.27	12.00	207.47	0.69	0.47	17.56
2018	9.70	11.70	197.36	0.83	0.53	8.53	12.00	209.21	0.71	0.47	18.23
2019	10.10	11.70	197.87	0.86	0.54	8.80	12.00	211.05	0.73	0.46	18.90
2020	10.53	11.70	198.67	0.90	0.54	9.05	12.00	212.94	0.75	0.46	19.57
2021	10.96	11.70	203.55	0.94	0.54	9.29	12.00	214.04	0.77	0.46	20.25
2022	11.23	14.70	204.00	0.76	0.54	9.69	12.00	215.66	0.81	0.46	20.92
2023	11.58	14.70	205.38	0.79	0.54	10.00	12.00	217.17	0.83	0.46	21.59
2024	11.95	14.70	206.95	0.81	0.54	10.31	12.00	218.63	0.86	0.46	22.26
2025	12.30	14.70	208.68	0.84	0.54	10.63	12.00	220.04	0.89	0.46	22.93
2026	12.65	14.70	209.79	0.86	0.54	10.95	12.00	225.62	0.91	0.46	23.60
2027	13.17	14.70	211.18	0.90	0.54	11.10	15.00	225.78	0.74	0.46	24.27
2028	13.57	14.70	216.20	0.92	0.54	11.37	15.00	227.58	0.76	0.46	24.94
2029	13.82	17.70	217.23	0.78	0.54	11.79	15.00	229.64	0.79	0.46	25.61
2030	14.17	17.70	218.99	0.80	0.54	12.11	15.00	231.73	0.81	0.46	26.28
2031	14.54	17.70	220.90	0.82	0.54	12.41	15.00	233.12	0.83	0.46	26.95
2032	14.88	17.70	222.91	0.84	0.54	12.74	15.00	234.80	0.85	0.46	27.62
2033	15.22	17.70	224.32	0.86	0.54	13.07	15.00	236.48	0.87	0.46	28.29
2034	15.58	17.70	225.84	0.88	0.54	13.38	15.00	238.07	0.89	0.46	28.96
2035	15.94	17.70	230.84	0.90	0.54	13.69	15.00	243.30	0.91	0.46	29.63

Table 2-5mln TEU per expansion time

Year	Rotterdam					Antwerp					Total volume
	Volume mlnTEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	Volume mln TEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	
2005	6.10	8.70	201.65	0.70	0.59	4.20	6.00	185.43	0.70	0.41	9.52
2006	6.03	8.70	198.10	0.69	0.52	4.15	6.00	182.96	0.69	0.48	10.19
2007	5.67	8.70	195.60	0.65	0.50	5.18	6.00	187.34	0.86	0.50	10.86
2008	5.75	8.70	194.86	0.66	0.51	5.78	6.00	199.94	0.96	0.49	11.53
2009	6.19	8.70	194.86	0.71	0.51	6.01	11.00	196.24	0.55	0.49	12.20
2010	6.51	8.70	193.40	0.75	0.51	6.36	11.00	198.38	0.58	0.49	12.87
2011	6.91	8.70	192.53	0.79	0.52	6.63	11.00	201.33	0.60	0.48	13.54
2012	7.38	8.70	192.11	0.85	0.53	6.83	11.00	203.93	0.62	0.47	14.21
2013	7.86	8.70	199.62	0.90	0.52	7.02	11.00	204.54	0.64	0.48	14.88
2014	8.11	13.70	199.23	0.59	0.52	7.44	11.00	206.41	0.68	0.48	15.55
2015	8.47	13.70	200.35	0.62	0.52	7.75	11.00	208.10	0.70	0.48	16.22
2016	8.84	13.70	201.89	0.65	0.52	8.06	11.00	209.54	0.73	0.48	16.89
2017	9.19	13.70	203.84	0.67	0.52	8.37	11.00	210.79	0.76	0.48	17.56
2018	9.53	13.70	204.67	0.70	0.52	8.70	11.00	212.25	0.79	0.48	18.23
2019	9.89	13.70	205.78	0.72	0.52	9.01	11.00	213.61	0.82	0.48	18.90
2020	10.25	13.70	206.91	0.75	0.52	9.32	11.00	214.93	0.85	0.48	19.57
2021	10.62	13.70	207.97	0.77	0.53	9.63	11.00	216.26	0.88	0.47	20.25
2022	10.98	13.70	208.87	0.80	0.54	9.93	11.00	224.72	0.90	0.46	20.92
2023	11.60	13.70	209.98	0.85	0.54	9.99	16.00	224.76	0.62	0.46	21.59
2024	12.06	13.70	211.00	0.88	0.55	10.20	16.00	226.94	0.64	0.45	22.26
2025	12.51	13.70	218.44	0.91	0.54	10.42	16.00	229.31	0.65	0.46	22.93
2026	12.74	18.70	219.41	0.68	0.54	10.86	16.00	232.13	0.68	0.46	23.60
2027	13.10	18.70	221.54	0.70	0.54	11.17	16.00	233.69	0.70	0.46	24.27
2028	13.44	18.70	223.87	0.72	0.54	11.50	16.00	235.59	0.72	0.46	24.94
2029	13.77	18.70	226.47	0.74	0.54	11.84	16.00	237.46	0.74	0.46	25.61
2030	14.09	18.70	228.10	0.75	0.54	12.19	16.00	239.25	0.76	0.46	26.28
2031	14.43	18.70	229.87	0.77	0.53	12.52	16.00	240.83	0.78	0.47	26.95
2032	14.77	18.70	231.59	0.79	0.53	12.85	16.00	242.42	0.80	0.47	27.62
2033	15.12	18.70	233.18	0.81	0.53	13.18	16.00	243.96	0.82	0.47	28.29
2034	15.47	18.70	234.59	0.83	0.53	13.50	16.00	245.45	0.84	0.47	28.96
2035	15.82	18.70	235.97	0.85	0.53	13.81	16.00	246.88	0.86	0.47	29.63

Table 3-7mln TEU per expansion time

Year	Rotterdam					Antwerp					Total volume
	Volume mlnTEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	Volume mln TEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	
2005	6.10	8.70	201.65	0.70	0.59	4.20	6.00	185.43	0.70	0.41	9.52
2006	6.03	8.70	198.10	0.69	0.52	4.15	6.00	182.96	0.69	0.48	10.19
2007	5.67	8.70	195.60	0.65	0.50	5.18	6.00	187.34	0.86	0.50	10.86
2008	5.75	8.70	194.86	0.66	0.51	5.78	6.00	204.17	0.96	0.49	11.53
2009	6.27	8.70	194.96	0.72	0.51	5.93	13.00	200.15	0.46	0.49	12.20
2010	6.63	8.70	193.57	0.76	0.52	6.24	13.00	202.96	0.48	0.48	12.87
2011	7.07	8.70	192.79	0.81	0.53	6.47	13.00	206.73	0.50	0.47	13.54
2012	7.57	8.70	192.48	0.87	0.54	6.64	13.00	210.33	0.51	0.46	14.21
2013	8.10	8.70	202.94	0.93	0.54	6.78	13.00	211.29	0.52	0.46	14.88
2014	8.32	15.70	202.88	0.53	0.53	7.23	13.00	213.69	0.56	0.47	15.55
2015	8.67	15.70	204.66	0.55	0.53	7.55	13.00	215.85	0.58	0.47	16.22
2016	9.03	15.70	206.98	0.58	0.53	7.86	13.00	217.69	0.60	0.47	16.89
2017	9.38	15.70	209.84	0.60	0.53	8.18	13.00	219.21	0.63	0.47	17.56
2018	9.69	15.70	211.16	0.62	0.53	8.54	13.00	220.91	0.66	0.47	18.23
2019	10.04	15.70	212.79	0.64	0.53	8.87	13.00	222.44	0.68	0.47	18.90
2020	10.39	15.70	214.41	0.66	0.53	9.19	13.00	223.86	0.71	0.47	19.57
2021	10.73	15.70	215.90	0.68	0.53	9.51	13.00	225.22	0.73	0.47	20.25
2022	11.08	15.70	217.12	0.71	0.53	9.84	13.00	226.57	0.76	0.47	20.92
2023	11.43	15.70	218.34	0.73	0.53	10.16	13.00	227.85	0.78	0.47	21.59
2024	11.79	15.70	219.49	0.75	0.53	10.47	13.00	229.11	0.81	0.47	22.26
2025	12.15	15.70	220.56	0.77	0.53	10.78	13.00	230.35	0.83	0.47	22.93
2026	12.51	15.70	221.55	0.80	0.53	11.09	13.00	231.58	0.85	0.47	23.60
2027	12.88	15.70	222.52	0.82	0.53	11.39	13.00	232.80	0.88	0.47	24.27
2028	13.25	15.70	223.45	0.84	0.53	11.69	13.00	234.03	0.90	0.47	24.94
2029	13.63	15.70	224.35	0.87	0.55	11.98	13.00	244.36	0.92	0.45	25.61
2030	14.38	15.70	233.98	0.92	0.54	11.90	20.00	244.33	0.59	0.46	26.28
2031	14.55	22.70	235.22	0.64	0.54	12.40	20.00	247.07	0.62	0.46	26.95
2032	14.87	22.70	237.76	0.66	0.54	12.75	20.00	250.00	0.64	0.46	27.62
2033	15.23	22.70	240.64	0.67	0.54	13.06	20.00	253.25	0.65	0.46	28.29
2034	15.61	22.70	243.93	0.69	0.54	13.36	20.00	255.08	0.67	0.46	28.96
2035	15.91	22.70	245.92	0.70	0.54	13.73	20.00	257.34	0.69	0.46	29.63

Table 4- Standard utilization at 90%

Year	Rotterdam					Antwerp					Total volume
	Volume mlnTEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	Volume mln TEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	
2005	6.10	8.70	201.65	0.70	0.59	4.20	6.00	185.43	0.70	0.41	9.52
2006	6.03	8.70	198.10	0.69	0.52	4.15	6.00	182.96	0.69	0.48	10.19
2007	5.67	8.70	195.60	0.65	0.50	5.18	6.00	187.34	0.86	0.50	10.86
2008	5.75	8.70	194.86	0.66	0.51	5.78	6.00	199.94	0.96	0.49	11.53
2009	6.19	8.70	194.86	0.71	0.51	6.01	11.00	196.24	0.55	0.49	12.20
2010	6.51	8.70	193.40	0.75	0.51	6.36	11.00	198.38	0.58	0.49	12.87
2011	6.91	8.70	192.53	0.79	0.52	6.63	11.00	201.33	0.60	0.48	13.54
2012	7.38	8.70	192.11	0.85	0.53	6.83	11.00	203.93	0.62	0.47	14.21
2013	7.86	8.70	199.62	0.90	0.52	7.02	11.00	204.54	0.64	0.48	14.88
2014	8.11	13.70	199.23	0.59	0.52	7.44	11.00	206.41	0.68	0.48	15.55
2015	8.47	13.70	200.35	0.62	0.52	7.75	11.00	208.10	0.70	0.48	16.22
2016	8.84	13.70	201.89	0.65	0.52	8.06	11.00	209.54	0.73	0.48	16.89
2017	9.19	13.70	203.84	0.67	0.52	8.37	11.00	210.79	0.76	0.48	17.56
2018	9.53	13.70	204.67	0.70	0.52	8.70	11.00	212.25	0.79	0.48	18.23
2019	9.89	13.70	205.78	0.72	0.52	9.01	11.00	213.61	0.82	0.48	18.90
2020	10.25	13.70	206.91	0.75	0.52	9.32	11.00	214.93	0.85	0.48	19.57
2021	10.62	13.70	207.97	0.77	0.53	9.63	11.00	216.26	0.88	0.47	20.25
2022	10.98	13.70	208.87	0.80	0.54	9.93	11.00	224.72	0.90	0.46	20.92
2023	11.60	13.70	209.98	0.85	0.54	9.99	16.00	224.76	0.62	0.46	21.59
2024	12.06	13.70	211.00	0.88	0.55	10.20	16.00	226.94	0.64	0.45	22.26
2025	12.51	13.70	218.44	0.91	0.54	10.42	16.00	229.31	0.65	0.46	22.93
2026	12.74	18.70	219.41	0.68	0.54	10.86	16.00	232.13	0.68	0.46	23.60
2027	13.10	18.70	221.54	0.70	0.54	11.17	16.00	233.69	0.70	0.46	24.27
2028	13.44	18.70	223.87	0.72	0.54	11.50	16.00	235.59	0.72	0.46	24.94
2029	13.77	18.70	226.47	0.74	0.54	11.84	16.00	237.46	0.74	0.46	25.61
2030	14.09	18.70	228.10	0.75	0.54	12.19	16.00	239.25	0.76	0.46	26.28
2031	14.43	18.70	229.87	0.77	0.53	12.52	16.00	240.83	0.78	0.47	26.95
2032	14.77	18.70	231.59	0.79	0.53	12.85	16.00	242.42	0.80	0.47	27.62
2033	15.12	18.70	233.18	0.81	0.53	13.18	16.00	243.96	0.82	0.47	28.29
2034	15.47	18.70	234.59	0.83	0.53	13.50	16.00	245.45	0.84	0.47	28.96
2035	15.82	18.70	235.97	0.85	0.53	13.81	16.00	246.88	0.86	0.47	29.63

Table 5- Standard utilization at 85%

Year	Rotterdam					Antwerp					Total volume
	Volume mlnTEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	Volume mln TEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	
2005	6.10	8.70	201.65	0.70	0.59	4.20	6.00	185.43	0.70	0.41	9.52
2006	6.03	8.70	198.10	0.69	0.52	4.15	6.00	182.96	0.69	0.48	10.19
2007	5.67	8.70	195.60	0.65	0.52	5.18	6.00	203.07	0.86	0.48	10.86
2008	6.03	8.70	195.34	0.69	0.52	5.50	11.00	200.15	0.50	0.48	11.53
2009	6.33	8.70	195.14	0.73	0.52	5.87	11.00	200.14	0.53	0.48	12.20
2010	6.66	8.70	193.75	0.77	0.52	6.21	11.00	203.06	0.56	0.48	12.87
2011	7.08	8.70	192.97	0.81	0.53	6.46	11.00	206.91	0.59	0.47	13.54
2012	7.58	8.70	200.76	0.87	0.53	6.63	11.00	207.44	0.60	0.47	14.21
2013	7.84	13.70	200.64	0.57	0.53	7.04	11.00	209.07	0.64	0.47	14.88
2014	8.19	13.70	201.66	0.60	0.53	7.36	11.00	210.92	0.67	0.47	15.55
2015	8.56	13.70	203.21	0.62	0.53	7.66	11.00	212.55	0.70	0.47	16.22
2016	8.93	13.70	205.24	0.65	0.53	7.97	11.00	213.77	0.72	0.47	16.89
2017	9.27	13.70	206.11	0.68	0.53	8.30	11.00	215.20	0.75	0.47	17.56
2018	9.63	13.70	207.21	0.70	0.53	8.61	11.00	216.58	0.78	0.47	18.23
2019	9.99	13.70	208.35	0.73	0.53	8.91	11.00	217.89	0.81	0.47	18.90
2020	10.36	13.70	209.41	0.76	0.53	9.22	11.00	219.16	0.84	0.47	19.57
2021	10.73	13.70	210.31	0.78	0.54	9.52	11.00	227.88	0.87	0.46	20.25
2022	11.34	13.70	211.41	0.83	0.55	9.57	16.00	228.29	0.60	0.45	20.92
2023	11.82	13.70	219.22	0.86	0.54	9.77	16.00	230.56	0.61	0.46	21.59
2024	12.05	18.70	220.48	0.64	0.54	10.21	16.00	233.28	0.64	0.46	22.26
2025	12.40	18.70	222.70	0.66	0.54	10.53	16.00	236.18	0.66	0.46	22.93
2026	12.77	18.70	225.20	0.68	0.54	10.82	16.00	237.89	0.68	0.46	23.60
2027	13.12	18.70	227.97	0.70	0.54	11.15	16.00	239.91	0.70	0.46	24.27
2028	13.44	18.70	229.73	0.72	0.54	11.50	16.00	241.91	0.72	0.46	24.94
2029	13.79	18.70	231.61	0.74	0.54	11.82	16.00	243.75	0.74	0.46	25.61
2030	14.14	18.70	233.43	0.76	0.54	12.14	16.00	245.39	0.76	0.46	26.28
2031	14.49	18.70	235.12	0.78	0.54	12.46	16.00	247.04	0.78	0.46	26.95
2032	14.85	18.70	236.60	0.79	0.54	12.78	16.00	248.61	0.80	0.46	27.62
2033	15.21	18.70	238.04	0.81	0.54	13.09	16.00	250.11	0.82	0.46	28.29
2034	15.57	18.70	239.40	0.83	0.54	13.39	16.00	251.55	0.84	0.46	28.96
2035	15.94	18.70	246.75	0.85	0.54	13.70	16.00	259.40	0.86	0.46	29.63

Table 6- Standard utilization at 80%

Year	Rotterdam					Antwerp					Total volume
	Volume mlnTEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	Volume mln TEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	
2005	6.10	8.70	201.65	0.70	0.59	4.20	6.00	185.43	0.70	0.41	9.52
2006	6.03	8.70	198.10	0.69	0.52	4.15	6.00	182.96	0.69	0.48	10.19
2007	5.67	8.70	195.60	0.65	0.52	5.18	6.00	203.07	0.86	0.48	10.86
2008	6.03	8.70	195.34	0.69	0.52	5.50	11.00	200.15	0.50	0.48	11.53
2009	6.33	8.70	195.14	0.73	0.52	5.87	11.00	200.14	0.53	0.48	12.20
2010	6.66	8.70	193.75	0.77	0.52	6.21	11.00	203.06	0.56	0.48	12.87
2011	7.08	8.70	201.60	0.81	0.52	6.46	11.00	206.91	0.59	0.48	13.54
2012	7.39	13.70	201.85	0.54	0.52	6.82	11.00	207.76	0.62	0.48	14.21
2013	7.73	13.70	203.05	0.56	0.52	7.16	11.00	209.33	0.65	0.48	14.88
2014	8.08	13.70	204.57	0.59	0.52	7.47	11.00	211.23	0.68	0.48	15.55
2015	8.44	13.70	206.69	0.62	0.52	7.79	11.00	212.93	0.71	0.48	16.22
2016	8.78	13.70	207.67	0.64	0.52	8.11	11.00	214.26	0.74	0.48	16.89
2017	9.14	13.70	208.83	0.67	0.52	8.43	11.00	215.70	0.77	0.48	17.56
2018	9.50	13.70	209.99	0.69	0.52	8.74	11.00	217.14	0.79	0.48	18.23
2019	9.86	13.70	211.10	0.72	0.53	9.04	11.00	226.29	0.82	0.47	18.90
2020	10.46	13.70	212.19	0.76	0.54	9.11	16.00	227.18	0.57	0.46	19.57
2021	10.94	13.70	213.24	0.80	0.55	9.30	16.00	229.65	0.58	0.45	20.25
2022	11.42	13.70	221.31	0.83	0.54	9.50	16.00	232.36	0.59	0.46	20.92
2023	11.66	18.70	222.77	0.62	0.54	9.93	16.00	235.56	0.62	0.46	21.59
2024	12.02	18.70	225.10	0.64	0.54	10.24	16.00	237.47	0.64	0.46	22.26
2025	12.36	18.70	227.68	0.66	0.54	10.56	16.00	239.60	0.66	0.46	22.93
2026	12.70	18.70	230.57	0.68	0.54	10.90	16.00	241.69	0.68	0.46	23.60
2027	13.02	18.70	232.43	0.70	0.54	11.25	16.00	243.68	0.70	0.46	24.27
2028	13.36	18.70	234.38	0.71	0.54	11.58	16.00	245.42	0.72	0.46	24.94
2029	13.70	18.70	236.26	0.73	0.53	11.91	16.00	247.13	0.74	0.47	25.61
2030	14.05	18.70	238.01	0.75	0.53	12.23	16.00	248.78	0.76	0.47	26.28
2031	14.39	18.70	239.54	0.77	0.53	12.56	16.00	250.34	0.78	0.47	26.95
2032	14.75	18.70	241.01	0.79	0.54	12.87	16.00	258.68	0.80	0.46	27.62
2033	15.40	18.70	248.84	0.82	0.54	12.89	21.00	259.94	0.61	0.46	28.29
2034	15.63	23.70	250.71	0.66	0.54	13.34	21.00	262.65	0.64	0.46	28.96
2035	15.95	23.70	253.26	0.67	0.54	13.68	21.00	265.50	0.65	0.46	29.63

Table 7- mainly Road

Year	Rotterdam					Antwerp					Total volume
	Volume mlnTEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	Volume mln TEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	
2005	6.10	8.70	211.88	0.70	0.59	4.20	6.00	191.86	0.70	0.41	9.52
2006	6.03	8.70	208.05	0.69	0.52	4.15	6.00	189.27	0.69	0.48	10.19
2007	5.61	8.70	205.22	0.65	0.49	5.24	6.00	194.15	0.87	0.51	10.86
2008	5.66	8.70	204.40	0.65	0.50	5.87	6.00	206.79	0.98	0.50	11.53
2009	6.09	8.70	204.37	0.70	0.50	6.11	11.00	202.89	0.56	0.50	12.20
2010	6.40	8.70	202.74	0.74	0.50	6.47	11.00	205.08	0.59	0.50	12.87
2011	6.80	8.70	201.73	0.78	0.51	6.74	11.00	208.10	0.61	0.49	13.54
2012	7.26	8.70	201.21	0.83	0.52	6.95	11.00	210.67	0.63	0.48	14.21
2013	7.74	8.70	200.85	0.89	0.53	7.14	11.00	211.24	0.65	0.47	14.88
2014	8.19	8.70	207.89	0.94	0.52	7.37	11.00	212.80	0.67	0.48	15.55
2015	8.45	13.70	207.38	0.62	0.52	7.77	11.00	214.58	0.71	0.48	16.22
2016	8.81	13.70	208.48	0.64	0.52	8.08	11.00	215.97	0.73	0.48	16.89
2017	9.18	13.70	209.92	0.67	0.52	8.39	11.00	217.15	0.76	0.48	17.56
2018	9.53	13.70	211.73	0.70	0.52	8.71	11.00	218.50	0.79	0.48	18.23
2019	9.86	13.70	212.50	0.72	0.52	9.04	11.00	219.87	0.82	0.48	18.90
2020	10.23	13.70	213.56	0.75	0.52	9.35	11.00	221.15	0.85	0.48	19.57
2021	10.59	13.70	214.63	0.77	0.52	9.66	11.00	222.44	0.88	0.48	20.25
2022	10.95	13.70	215.64	0.80	0.54	9.96	11.00	230.85	0.91	0.46	20.92
2023	11.56	13.70	216.69	0.84	0.54	10.03	16.00	230.83	0.63	0.46	21.59
2024	12.02	13.70	217.70	0.88	0.54	10.24	16.00	232.98	0.64	0.46	22.26
2025	12.47	13.70	225.17	0.91	0.54	10.46	16.00	235.30	0.65	0.46	22.93
2026	12.69	18.70	226.16	0.68	0.54	10.91	16.00	238.09	0.68	0.46	23.60
2027	13.04	18.70	228.28	0.70	0.54	11.23	16.00	239.63	0.70	0.46	24.27
2028	13.38	18.70	230.62	0.72	0.54	11.56	16.00	241.51	0.72	0.46	24.94
2029	13.71	18.70	233.21	0.73	0.53	11.90	16.00	243.35	0.74	0.47	25.61
2030	14.02	18.70	234.84	0.75	0.53	12.26	16.00	245.14	0.77	0.47	26.28
2031	14.36	18.70	236.61	0.77	0.53	12.59	16.00	246.70	0.79	0.47	26.95
2032	14.70	18.70	238.32	0.79	0.53	12.92	16.00	248.28	0.81	0.47	27.62
2033	15.04	18.70	239.91	0.80	0.53	13.25	16.00	249.82	0.83	0.47	28.29
2034	15.39	18.70	241.31	0.82	0.53	13.58	16.00	251.31	0.85	0.47	28.96
2035	15.74	18.70	242.68	0.84	0.53	13.89	16.00	252.74	0.87	0.47	29.63

Table 8- mainly railway

Year	Rotterdam					Antwerp					Total volume
	Volume mlnTEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	Volume mln TEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	
2005	6.10	8.70	150.27	0.70	0.59	4.20	6.00	143.92	0.70	0.41	9.52
2006	6.03	8.70	148.05	0.69	0.54	4.15	6.00	142.24	0.69	0.46	10.19
2007	5.83	8.70	146.71	0.67	0.52	5.03	6.00	145.15	0.84	0.48	10.86
2008	5.95	8.70	146.31	0.68	0.53	5.58	6.00	157.68	0.93	0.47	11.53
2009	6.41	8.70	146.39	0.74	0.53	5.78	11.00	154.55	0.53	0.47	12.20
2010	6.76	8.70	145.63	0.78	0.53	6.10	11.00	156.66	0.55	0.47	12.87
2011	7.18	8.70	145.27	0.82	0.54	6.36	11.00	159.48	0.58	0.46	13.54
2012	7.63	8.70	145.21	0.88	0.55	6.58	11.00	162.25	0.60	0.45	14.21
2013	8.11	8.70	152.85	0.93	0.54	6.77	11.00	163.07	0.62	0.46	14.88
2014	8.37	13.70	152.70	0.61	0.54	7.18	11.00	164.97	0.65	0.46	15.55
2015	8.73	13.70	154.10	0.64	0.54	7.49	11.00	166.72	0.68	0.46	16.22
2016	9.10	13.70	155.88	0.66	0.54	7.79	11.00	168.28	0.71	0.46	16.89
2017	9.46	13.70	158.04	0.69	0.54	8.10	11.00	169.63	0.74	0.46	17.56
2018	9.80	13.70	159.10	0.72	0.54	8.43	11.00	171.14	0.77	0.46	18.23
2019	10.16	13.70	160.42	0.74	0.54	8.74	11.00	172.58	0.79	0.46	18.90
2020	10.53	13.70	161.75	0.77	0.54	9.05	11.00	173.97	0.82	0.46	19.57
2021	10.89	13.70	163.00	0.79	0.54	9.36	11.00	175.35	0.85	0.46	20.25
2022	11.26	13.70	164.09	0.82	0.54	9.66	11.00	176.78	0.88	0.46	20.92
2023	11.63	13.70	165.20	0.85	0.55	9.95	11.00	185.27	0.90	0.45	21.59
2024	12.26	13.70	166.45	0.89	0.55	10.00	16.00	185.42	0.63	0.45	22.26
2025	12.72	13.70	173.93	0.93	0.55	10.21	16.00	187.70	0.64	0.45	22.93
2026	12.95	18.70	174.95	0.69	0.55	10.65	16.00	190.35	0.67	0.45	23.60
2027	13.31	18.70	177.16	0.71	0.55	10.96	16.00	193.15	0.68	0.45	24.27
2028	13.69	18.70	179.60	0.73	0.55	11.24	16.00	194.81	0.70	0.45	24.94
2029	14.04	18.70	182.27	0.75	0.55	11.57	16.00	196.81	0.72	0.45	25.61
2030	14.37	18.70	183.98	0.77	0.55	11.91	16.00	198.77	0.74	0.45	26.28
2031	14.73	18.70	185.85	0.79	0.55	12.22	16.00	200.59	0.76	0.45	26.95
2032	15.09	18.70	187.66	0.81	0.55	12.54	16.00	202.23	0.78	0.45	27.62
2033	15.44	18.70	189.34	0.83	0.55	12.85	16.00	203.87	0.80	0.45	28.29
2034	15.80	18.70	190.84	0.84	0.55	13.16	16.00	205.45	0.82	0.45	28.96
2035	16.17	18.70	192.30	0.86	0.55	13.47	16.00	206.97	0.84	0.45	29.63

Table 9- mainly inland waterway

Year	Rotterdam					Antwerp					Total volume
	Volume mlnTEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	Volume mln TEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	
2005	6.10	8.70	161.25	0.70	0.59	4.20	6.00	153.03	0.70	0.41	9.52
2006	6.03	8.70	158.75	0.69	0.53	4.15	6.00	151.17	0.69	0.47	10.19
2007	5.80	8.70	157.19	0.67	0.51	5.06	6.00	154.35	0.84	0.49	10.86
2008	5.91	8.70	156.71	0.68	0.52	5.62	6.00	166.89	0.94	0.48	11.53
2009	6.37	8.70	156.77	0.73	0.52	5.83	11.00	163.64	0.53	0.48	12.20
2010	6.72	8.70	155.87	0.77	0.53	6.15	11.00	165.75	0.56	0.47	12.87
2011	7.13	8.70	155.41	0.82	0.53	6.41	11.00	168.59	0.58	0.47	13.54
2012	7.58	8.70	155.28	0.87	0.54	6.63	11.00	171.32	0.60	0.46	14.21
2013	8.06	8.70	162.88	0.93	0.54	6.82	11.00	172.10	0.62	0.46	14.88
2014	8.32	13.70	162.68	0.61	0.54	7.23	11.00	173.98	0.66	0.46	15.55
2015	8.68	13.70	164.02	0.63	0.54	7.54	11.00	175.72	0.69	0.46	16.22
2016	9.05	13.70	165.75	0.66	0.54	7.84	11.00	177.25	0.71	0.46	16.89
2017	9.41	13.70	167.86	0.69	0.53	8.15	11.00	178.58	0.74	0.47	17.56
2018	9.75	13.70	168.87	0.71	0.53	8.48	11.00	180.08	0.77	0.47	18.23
2019	10.11	13.70	170.15	0.74	0.54	8.79	11.00	181.49	0.80	0.46	18.90
2020	10.47	13.70	171.43	0.76	0.54	9.10	11.00	182.86	0.83	0.46	19.57
2021	10.84	13.70	172.64	0.79	0.54	9.41	11.00	184.24	0.86	0.46	20.25
2022	11.21	13.70	173.69	0.82	0.54	9.71	11.00	185.65	0.88	0.46	20.92
2023	11.58	13.70	174.76	0.85	0.55	10.00	11.00	194.09	0.91	0.45	21.59
2024	12.20	13.70	175.98	0.89	0.55	10.05	16.00	194.16	0.63	0.45	22.26
2025	12.67	13.70	183.45	0.92	0.55	10.26	16.00	196.41	0.64	0.45	22.93
2026	12.89	18.70	184.46	0.69	0.55	10.70	16.00	199.03	0.67	0.45	23.60
2027	13.25	18.70	186.64	0.71	0.55	11.02	16.00	201.79	0.69	0.45	24.27
2028	13.63	18.70	189.06	0.73	0.55	11.31	16.00	203.41	0.71	0.45	24.94
2029	13.97	18.70	191.72	0.75	0.54	11.64	16.00	205.39	0.73	0.46	25.61
2030	14.30	18.70	193.41	0.76	0.54	11.98	16.00	207.33	0.75	0.46	26.28
2031	14.66	18.70	195.26	0.78	0.54	12.30	16.00	209.13	0.77	0.46	26.95
2032	15.01	18.70	197.04	0.80	0.54	12.61	16.00	210.75	0.79	0.46	27.62
2033	15.37	18.70	198.71	0.82	0.54	12.93	16.00	212.38	0.81	0.46	28.29
2034	15.72	18.70	200.19	0.84	0.54	13.24	16.00	213.95	0.83	0.46	28.96
2035	16.09	18.70	201.63	0.86	0.54	13.55	16.00	215.45	0.85	0.46	29.63

Table 10- equal hinterland infrastructure growth rate

Year	Rotterdam					Antwerp					Total volume
	Volume mlnTEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	Volume mln TEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	
2005	6.10	8.70	201.65	0.70	0.59	4.20	6.00	185.43	0.70	0.41	9.52
2006	6.03	8.70	198.10	0.69	0.52	4.15	6.00	182.06	0.69	0.48	10.19
2007	5.66	8.70	195.57	0.65	0.50	5.20	6.00	185.89	0.87	0.50	10.86
2008	5.71	8.70	194.80	0.66	0.50	5.82	6.00	198.16	0.97	0.50	11.53
2009	6.14	8.70	194.77	0.71	0.50	6.06	11.00	194.25	0.55	0.50	12.20
2010	6.44	8.70	193.28	0.74	0.50	6.43	11.00	195.87	0.58	0.50	12.87
2011	6.83	8.70	192.36	0.78	0.51	6.71	11.00	198.42	0.61	0.49	13.54
2012	7.27	8.70	191.88	0.84	0.52	6.94	11.00	200.70	0.63	0.48	14.21
2013	7.73	8.70	191.54	0.89	0.52	7.15	11.00	201.00	0.65	0.48	14.88
2014	8.16	8.70	198.65	0.94	0.52	7.39	11.00	202.24	0.67	0.48	15.55
2015	8.40	13.70	198.20	0.61	0.52	7.82	11.00	203.70	0.71	0.48	16.22
2016	8.74	13.70	199.33	0.64	0.52	8.15	11.00	204.85	0.74	0.48	16.89
2017	9.09	13.70	200.80	0.66	0.52	8.48	11.00	205.80	0.77	0.48	17.56
2018	9.42	13.70	202.64	0.69	0.51	8.82	11.00	206.94	0.80	0.49	18.23
2019	9.73	13.70	203.43	0.71	0.51	9.17	11.00	208.12	0.83	0.49	18.90
2020	10.08	13.70	204.50	0.74	0.51	9.50	11.00	209.24	0.86	0.49	19.57
2021	10.42	13.70	205.58	0.76	0.51	9.82	11.00	210.40	0.89	0.49	20.25
2022	10.77	13.70	206.59	0.79	0.53	10.15	11.00	218.57	0.92	0.47	20.92
2023	11.36	13.70	207.63	0.83	0.53	10.23	16.00	218.30	0.64	0.47	21.59
2024	11.79	13.70	208.62	0.86	0.53	10.47	16.00	220.31	0.65	0.47	22.26
2025	12.22	13.70	209.62	0.89	0.54	10.70	16.00	222.52	0.67	0.46	22.93
2026	12.66	13.70	216.97	0.92	0.53	10.93	16.00	224.93	0.68	0.47	23.60
2027	12.88	18.70	217.87	0.69	0.53	11.39	16.00	226.40	0.71	0.47	24.27
2028	13.19	18.70	219.92	0.71	0.53	11.75	16.00	228.15	0.73	0.47	24.94
2029	13.50	18.70	222.19	0.72	0.53	12.11	16.00	229.86	0.76	0.47	25.61
2030	13.81	18.70	224.73	0.74	0.52	12.47	16.00	231.49	0.78	0.48	26.28
2031	14.11	18.70	226.29	0.75	0.52	12.85	16.00	233.00	0.80	0.48	26.95
2032	14.42	18.70	228.01	0.77	0.52	13.20	16.00	234.51	0.82	0.48	27.62
2033	14.75	18.70	229.67	0.79	0.52	13.55	16.00	235.98	0.85	0.48	28.29
2034	15.07	18.70	231.21	0.81	0.52	13.89	16.00	237.42	0.87	0.48	28.96
2035	15.41	18.70	232.57	0.82	0.52	14.23	16.00	238.84	0.89	0.48	29.63

Table 11- higher hinterland infrastructure growth rate in Rotterdam

Year	Rotterdam					Antwerp					Total volume
	Volume mlnTEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	Volume mln TEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	
2005	6.10	8.70	201.65	0.70	0.59	4.20	6.00	185.43	0.70	0.41	9.52
2006	6.03	8.70	197.22	0.69	0.52	4.15	6.00	182.96	0.69	0.48	10.19
2007	5.69	8.70	194.55	0.65	0.50	5.17	6.00	187.25	0.86	0.50	10.86
2008	5.77	8.70	193.72	0.66	0.51	5.76	6.00	199.82	0.96	0.49	11.53
2009	6.22	8.70	193.64	0.71	0.51	5.98	11.00	196.18	0.54	0.49	12.20
2010	6.55	8.70	191.91	0.75	0.51	6.32	11.00	198.29	0.57	0.49	12.87
2011	6.96	8.70	190.88	0.80	0.52	6.57	11.00	201.20	0.60	0.48	13.54
2012	7.44	8.70	190.31	0.85	0.53	6.77	11.00	203.78	0.62	0.47	14.21
2013	7.93	8.70	197.61	0.91	0.53	6.95	11.00	204.38	0.63	0.47	14.88
2014	8.19	13.70	197.01	0.60	0.53	7.36	11.00	206.21	0.67	0.47	15.55
2015	8.56	13.70	197.98	0.62	0.53	7.66	11.00	207.85	0.70	0.47	16.22
2016	8.94	13.70	199.38	0.65	0.53	7.95	11.00	209.25	0.72	0.47	16.89
2017	9.31	13.70	201.19	0.68	0.53	8.25	11.00	210.46	0.75	0.47	17.56
2018	9.65	13.70	201.89	0.70	0.53	8.58	11.00	211.86	0.78	0.47	18.23
2019	10.02	13.70	202.89	0.73	0.53	8.88	11.00	213.16	0.81	0.47	18.90
2020	10.40	13.70	203.92	0.76	0.53	9.18	11.00	214.41	0.83	0.47	19.57
2021	10.77	13.70	204.88	0.79	0.53	9.48	11.00	215.67	0.86	0.47	20.25
2022	11.14	13.70	205.70	0.81	0.53	9.77	11.00	216.97	0.89	0.47	20.92
2023	11.53	13.70	206.56	0.84	0.55	10.06	11.00	225.27	0.91	0.45	21.59
2024	12.15	13.70	207.59	0.89	0.55	10.10	16.00	225.12	0.63	0.45	22.26
2025	12.62	13.70	214.89	0.92	0.54	10.31	16.00	227.22	0.64	0.46	22.93
2026	12.85	18.70	215.74	0.69	0.54	10.75	16.00	229.73	0.67	0.46	23.60
2027	13.20	18.70	217.77	0.71	0.54	11.07	16.00	232.37	0.69	0.46	24.27
2028	13.59	18.70	220.05	0.73	0.54	11.35	16.00	233.86	0.71	0.46	24.94
2029	13.93	18.70	222.57	0.74	0.54	11.68	16.00	235.73	0.73	0.46	25.61
2030	14.26	18.70	224.14	0.76	0.54	12.02	16.00	237.58	0.75	0.46	26.28
2031	14.61	18.70	225.86	0.78	0.54	12.34	16.00	239.28	0.77	0.46	26.95
2032	14.97	18.70	227.54	0.80	0.54	12.65	16.00	240.80	0.79	0.46	27.62
2033	15.33	18.70	229.10	0.82	0.54	12.97	16.00	242.36	0.81	0.46	28.29
2034	15.68	18.70	230.48	0.84	0.54	13.28	16.00	243.85	0.83	0.46	28.96
2035	16.05	18.70	231.84	0.86	0.54	13.58	16.00	245.28	0.85	0.46	29.63

Table 12- higher hinterland infrastructure growth rate in Antwerp

Year	Rotterdam Volume mlnTEU	Rotterdam Capacity mln TEU	Rotterdam Total Unit cost (EURO)	Rotterdam Utilization (%)	Rotterdam Market share (%)	Antwerp Volume mln TEU	Antwerp Capacity mln TEU	Antwerp Total Unit cost (EURO)	Antwerp Utilization (%)	Antwerp Market share (%)	Total volume
2005	6.10	8.70	201.65	0.70	0.59	4.20	6.00	185.43	0.70	0.41	9.52
2006	6.03	8.70	199.06	0.69	0.52	4.15	6.00	181.25	0.69	0.48	10.19
2007	5.63	8.70	196.75	0.65	0.49	5.23	6.00	184.74	0.87	0.51	10.86
2008	5.65	8.70	196.09	0.65	0.50	5.87	6.00	196.82	0.98	0.50	11.53
2009	6.05	8.70	196.18	0.70	0.49	6.14	11.00	192.72	0.56	0.51	12.20
2010	6.34	8.70	195.04	0.73	0.49	6.53	11.00	193.97	0.59	0.51	12.87
2011	6.70	8.70	194.32	0.77	0.50	6.84	11.00	196.30	0.62	0.50	13.54
2012	7.11	8.70	194.03	0.82	0.51	7.10	11.00	198.40	0.65	0.49	14.21
2013	7.55	8.70	193.89	0.87	0.51	7.34	11.00	198.54	0.67	0.49	14.88
2014	7.94	8.70	201.40	0.91	0.50	7.61	11.00	199.63	0.69	0.50	15.55
2015	8.15	13.70	201.28	0.60	0.50	8.07	11.00	200.97	0.73	0.50	16.22
2016	8.46	13.70	202.64	0.62	0.50	8.43	11.00	202.03	0.77	0.50	16.89
2017	8.77	13.70	204.35	0.64	0.50	8.79	11.00	202.92	0.80	0.50	17.56
2018	9.07	13.70	206.43	0.66	0.50	9.16	11.00	204.04	0.83	0.50	18.23
2019	9.36	13.70	207.42	0.68	0.49	9.55	11.00	205.22	0.87	0.51	18.90
2020	9.67	13.70	208.67	0.71	0.50	9.90	11.00	213.50	0.90	0.50	19.57
2021	10.22	13.70	210.10	0.75	0.51	10.03	16.00	213.45	0.63	0.49	20.25
2022	10.62	13.70	211.36	0.77	0.51	10.30	16.00	215.53	0.64	0.49	20.92
2023	11.02	13.70	212.48	0.80	0.51	10.57	16.00	217.83	0.66	0.49	21.59
2024	11.43	13.70	213.64	0.83	0.52	10.83	16.00	220.35	0.68	0.48	22.26
2025	11.86	13.70	214.82	0.87	0.52	11.07	16.00	221.72	0.69	0.48	22.93
2026	12.26	13.70	215.94	0.89	0.52	11.34	16.00	223.41	0.71	0.48	23.60
2027	12.65	13.70	223.39	0.92	0.51	11.62	16.00	225.03	0.73	0.49	24.27
2028	12.80	18.70	224.36	0.68	0.51	12.14	16.00	226.74	0.76	0.49	24.94
2029	13.07	18.70	226.49	0.70	0.51	12.54	16.00	228.20	0.78	0.49	25.61
2030	13.35	18.70	228.82	0.71	0.51	12.93	16.00	229.70	0.81	0.49	26.28
2031	13.62	18.70	231.40	0.73	0.50	13.33	16.00	231.19	0.83	0.50	26.95
2032	13.88	18.70	233.00	0.74	0.50	13.75	16.00	232.69	0.86	0.50	27.62
2033	14.17	18.70	234.76	0.76	0.50	14.13	16.00	234.14	0.88	0.50	28.29
2034	14.46	18.70	236.44	0.77	0.51	14.50	16.00	241.67	0.91	0.49	28.96
2035	15.05	18.70	238.18	0.80	0.51	14.58	21.00	242.06	0.69	0.49	29.63

Table 13- Global economy boom

Year	Rotterdam					Antwerp					Total volume
	Volume mlnTEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	Volume mln TEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	
2005	6.10	8.70	201.65	0.70	0.59	4.20	6.00	185.43	0.70	0.41	9.52
2006	6.23	8.70	198.95	0.72	0.52	4.29	6.00	183.97	0.71	0.48	10.52
2007	6.02	8.70	196.75	0.69	0.52	5.50	6.00	204.57	0.92	0.48	11.52
2008	6.55	8.70	196.78	0.75	0.52	5.96	11.00	201.25	0.54	0.48	12.52
2009	7.01	8.70	196.79	0.81	0.52	6.50	11.00	201.55	0.59	0.48	13.52
2010	7.50	8.70	195.95	0.86	0.52	7.01	11.00	205.02	0.64	0.48	14.52
2011	8.11	8.70	203.30	0.93	0.52	7.41	11.00	209.30	0.67	0.48	15.52
2012	8.60	13.70	203.20	0.63	0.52	7.92	11.00	210.58	0.72	0.48	16.52
2013	9.14	13.70	204.52	0.67	0.52	8.38	11.00	212.73	0.76	0.48	17.52
2014	9.70	13.70	206.14	0.71	0.53	8.82	11.00	215.28	0.80	0.47	18.52
2015	10.27	13.70	208.28	0.75	0.53	9.25	11.00	217.66	0.84	0.47	19.52
2016	10.83	13.70	209.41	0.79	0.53	9.69	11.00	219.75	0.88	0.47	20.52
2017	11.40	13.70	210.82	0.83	0.54	10.11	11.00	228.99	0.92	0.46	21.52
2018	12.23	13.70	212.53	0.89	0.55	10.28	16.00	229.61	0.64	0.45	22.52
2019	12.89	13.70	220.38	0.94	0.54	10.62	16.00	232.47	0.66	0.46	23.52
2020	13.31	18.70	221.56	0.71	0.54	11.20	16.00	235.76	0.70	0.46	24.52
2021	13.87	18.70	224.07	0.74	0.55	11.65	16.00	239.13	0.73	0.45	25.52
2022	14.46	18.70	226.83	0.77	0.55	12.06	16.00	241.31	0.75	0.45	26.52
2023	15.00	18.70	229.78	0.80	0.54	12.51	16.00	243.88	0.78	0.46	27.52
2024	15.53	18.70	231.76	0.83	0.55	12.99	16.00	246.44	0.81	0.45	28.52
2025	16.09	18.70	233.94	0.86	0.55	13.43	16.00	248.83	0.84	0.45	29.52
2026	16.65	18.70	236.08	0.89	0.55	13.86	16.00	251.06	0.87	0.45	30.52
2027	17.21	18.70	243.73	0.92	0.54	14.30	16.00	253.33	0.89	0.46	31.52
2028	17.50	23.70	245.50	0.74	0.54	15.02	16.00	261.87	0.94	0.46	32.52
2029	18.25	23.70	248.42	0.77	0.54	15.27	21.00	262.67	0.73	0.46	33.52
2030	18.79	23.70	251.39	0.79	0.54	15.72	21.00	265.59	0.75	0.46	34.52
2031	19.33	23.70	254.54	0.82	0.54	16.18	21.00	268.67	0.77	0.46	35.52
2032	19.87	23.70	256.80	0.84	0.55	16.64	21.00	271.93	0.79	0.45	36.52
2033	20.47	23.70	259.20	0.86	0.55	17.04	21.00	274.08	0.81	0.45	37.52
2034	21.03	23.70	261.48	0.89	0.55	17.49	21.00	276.56	0.83	0.45	38.52
2035	21.60	23.70	268.81	0.91	0.54	17.92	21.00	278.96	0.85	0.46	39.52

Table 14- Global economy crisis

Year	Rotterdam					Antwerp					Total volume
	Volume mlnTEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	Volume mln TEU	Capacity mln TEU	Total Unit cost (EURO)	Utilization (%)	Market share (%)	
2005	6.10	8.70	201.65	0.70	0.59	4.20	6.00	185.43	0.70	0.41	9.52
2006	5.90	8.70	197.53	0.68	0.52	4.06	6.00	182.29	0.68	0.48	9.96
2007	5.44	8.70	194.85	0.63	0.50	4.97	6.00	185.84	0.83	0.50	10.41
2008	5.40	8.70	193.97	0.62	0.51	5.46	6.00	198.35	0.91	0.49	10.86
2009	5.71	8.70	193.82	0.66	0.50	5.59	11.00	195.22	0.51	0.50	11.30
2010	5.93	8.70	192.06	0.68	0.51	5.82	11.00	196.97	0.53	0.49	11.75
2011	6.22	8.70	190.89	0.72	0.52	5.98	11.00	199.63	0.54	0.48	12.20
2012	6.56	8.70	190.12	0.75	0.53	6.09	11.00	202.08	0.55	0.47	12.64
2013	6.91	8.70	189.43	0.79	0.53	6.18	11.00	202.53	0.56	0.47	13.09
2014	7.24	8.70	188.63	0.83	0.54	6.30	11.00	203.79	0.57	0.46	13.54
2015	7.56	8.70	188.07	0.87	0.55	6.42	11.00	204.96	0.58	0.45	13.99
2016	7.89	8.70	195.42	0.91	0.54	6.54	11.00	205.86	0.59	0.46	14.43
2017	8.03	13.70	195.11	0.59	0.54	6.85	11.00	206.73	0.62	0.46	14.88
2018	8.24	13.70	196.17	0.60	0.54	7.08	11.00	207.58	0.64	0.46	15.33
2019	8.47	13.70	197.62	0.62	0.54	7.31	11.00	208.37	0.66	0.46	15.77
2020	8.68	13.70	199.48	0.63	0.53	7.54	11.00	209.11	0.69	0.47	16.22
2021	8.88	13.70	200.24	0.65	0.53	7.79	11.00	209.85	0.71	0.47	16.67
2022	9.09	13.70	201.23	0.66	0.53	8.02	11.00	210.55	0.73	0.47	17.11
2023	9.31	13.70	202.23	0.68	0.53	8.25	11.00	211.24	0.75	0.47	17.56
2024	9.53	13.70	203.13	0.70	0.53	8.48	11.00	211.93	0.77	0.47	18.01
2025	9.75	13.70	203.86	0.71	0.53	8.71	11.00	212.62	0.79	0.47	18.46
2026	9.98	13.70	204.59	0.73	0.53	8.93	11.00	213.30	0.81	0.47	18.90
2027	10.21	13.70	205.28	0.75	0.53	9.14	11.00	213.99	0.83	0.47	19.35
2028	10.44	13.70	205.91	0.76	0.53	9.36	11.00	214.70	0.85	0.47	19.80
2029	10.68	13.70	206.50	0.78	0.53	9.57	11.00	215.42	0.87	0.47	20.24
2030	10.92	13.70	207.07	0.80	0.53	9.77	11.00	216.16	0.89	0.47	20.69
2031	11.16	13.70	207.62	0.81	0.54	9.98	11.00	223.97	0.91	0.46	21.14
2032	11.64	13.70	208.30	0.85	0.54	9.94	16.00	223.52	0.62	0.46	21.58
2033	11.97	13.70	208.91	0.87	0.55	10.06	16.00	225.23	0.63	0.45	22.03
2034	12.30	13.70	209.52	0.90	0.55	10.18	16.00	227.15	0.64	0.45	22.48
2035	12.63	13.70	216.53	0.92	0.55	10.29	16.00	229.31	0.64	0.45	22.93

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