Barging on the Rhine and the challenge for the port of Rotterdam

Master Thesis

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Abstract

In this thesis, I have made a study on hinterland connections. The emphasis is on the barging problem in the port of Rotterdam. Barging is one of the transportation modalities that is gaining share, and is expected to gain more due to its competitive advantage over the other modes and the fact that it is the preferred mode of the authorities in the Netherlands because of its environmentally clean characteristics and the fact that it does not clog up the transport infrastructure on roads and railways.

Within the port however, there is quite some congestion due to barging. The reasons for this lie in the fact that the developments in barging over the Rhine are rooted in the history and the upcoming of the container trade by barge. Historically the way barging is organised does make sense with respect to optimisation of freight consolidation in the hinterland, but in the port because of the grown volumes the situation is far from optimal.

This congestion is harmful for all actors in the transportation chain, as extra costs are incurred as a result of the delays, and affects the overall competitive position of the port of Rotterdam.

I have looked into different configurations that could solve the congestion in the port without affecting the hinterland haulage. Hereto six different models of barging have been proposed and analysed.

The main difficulty encountered in the modelling consists of the trade off between extra costs involved and the gain of efficiency. This proves that the ideal solution is probably nowhere to be found.

Although the modelling sounds quite straight forward on paper, I have found that the difference between theoretical and practical solutions can be large. A better solution will make all parties better off eventually, but it remains to be seen who will be willing to invest, and to be the first to change the current calling patterns.

The implementation of the theoretical models can therefore not be used without further studies, but the urgency on the ground, if the container transport will pick up again might push the actors involved towards the adoption of a quick solution.

On top of this I have constructed a calculation model that can compute the optimal sailing pattern for a given demand in the river. This model optimises the total time incurred by a certain pattern and can be used to reduce the number of port calls and thus diminish congestion.

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Section 1

Introduction

Technological developments in transportation and communication have helped to change the way business is conducted worldwide (Talley, 2000). Standardisation in handling of general cargo notably through the rise of containers and economies of scale with ever larger ships have made transportation tremendously cheap. This, with the accessibility of information through computers and especially computer networks, have shaped the world's economies in such way that production can be easily outsourced or offshored to remote locations where raw materials or labour are more abundant or affordable. This process of globalisation has spurred up trade dramatically.

To accommodate this trade with ever increasing volumes, as not only trade flourishes well but also world population growth and an increase in wealth bring along a higher overall consumption, transportation systems had to adapt accordingly. Ports have changed along the same lines and do not function purely as a place for cargo haulage any more, but became locations for complex networks of companies and industries that add economic value to the entire port cluster.

With these developments the role of the port authorities has changed as well. Gradually the position of the port authorities became independent of the governments and other stakeholders, mainly through corporatisation. The influence of the port authorities has grown over the last years as strategic decisions made in the port can affect the distribution chain all the way up the farthest corners of the hinterland.

Environmental awareness in the western world is increasingly forcing companies to opt for cleaner solutions. In the transport industry this means a shift towards more sustainable modes of transport. Cleaner engines have helped a lot to cut down on the emissions of pollutants. However with trade on the rise and transportation derived from it as well, the calls for decoupling of the two is ever more heard. Besides the pollution from the transport vehicles also congestion is increasing. In many parts of Europe and the United States of America traffic jams are daily recurring problems around the larger cities. In port cities these traffic jams are caused not only by commuters alone but also by the haulage of cargo. Therefore cargo haulage comes more and more under social pressure to come up with solutions to these problems. Here in the Netherlands the emphasis lies in a shift to barge and rail. Both are considered cleaner per tonne kilometre than trucking and they put no further pressure on the road infrastructure. Railway requires expensive infrastructure that often is built with public money, barging however requires little investments in infrastructure as natural waterways and already dug canals can be used.

The barge connections on the river Rhine are unique both in terms of volume and organisational structure. From its infancy the Rhine barge connections from the mainly German hinterland in the Rhine and Ruhr areas have been working on optimisation of the transport flows. The development is such that three distinct areas can be pointed out in the hinterland that more or less function as autonomous regions regarding to the transportation.

With further increasing volumes of containers, the emergence of more terminals and larger barge capacity, the organisational advantage of the way the transports are organised in terms of calling patterns as well as the freight consolidations on board, in the current situation, only results in a optimisation in the hinterland. In the gateway seaports the picture is totally different. The number of calls went up and the turn around time increased dramatically. The current situation leads to a sub- optimal solution for the entire chain because the cost structure and call patterns have not changed. The average number of calls a barge makes in the port of Rotterdam lies somewhere between eight and thirteen. This together with the long waiting times at the terminals and depots makes a turn around time of three days no exception any more, where one day was the average fifteen years ago. The sailing schedules still function as if the turnaround time in the ports amounts up to a day leading to a inefficient usage of the vessels. Time in port is seen as unproductive as barges only make money when sailing.

From a port point of view the numerous ships that lie waiting take up precious place, and the sheer number of movements in the ports between the different load and discharge points is seen as challenge in itself. From a point of view of the entire transport chain, the number of calls in the port and the prolonged turn around time are seen as inefficiencies and cost factors to take into account.

In this writing I will try to come up with solutions that can help meet this challenge. This thesis is therefore centred along the following research question:

How can the hinterland transport of containers by barge on the Rhine be organised in such way that both hinterland schedules and gateway seaport calls are optimised?

Subsequently the sub-questions I have formulated and that will be answered along this work are the following:

How are the current transports organised and what are the main bottle-necks?
In what way do improvements in the seaport calling patterns affect the optimality in the hinterland?
How to find and implement a solution that is acceptable according to all parties involved?

I have chosen for a qualitative approach to the problem. As a result of this I will try to come up with solutions that can be useful in tackling the issues of congestion. For easy implementation of the suggested solutions I have narrowed down the problem to a pure sailing problem. Other solutions involving technological innovations or important infrastructural investments are left out because the simple fact that they would require both time and money before solving anything. The situation is according to me too urgent and probably also of temporary nature to justify the time and the sums of money involved.

The structure of the thesis is as follows. In section 2 I will have an in depth historical analysis on containerisation in general and how it has affected the landscape of the transportation industry, a brief introduction of the port of Rotterdam and an analysis of the barging world with the emphasis on the Rhine trade. I will conclude that section with a short summary of the current situation on Rhine barging from Rotterdam. Section 3 will hold a literature review, mainly on port developments and port competition. The focus will be on the importance of hinterland connections for ports, and how they affect decision making of parties involved in the transportation chain. Section 4 will be the home of the models that I propose as solutions to the problem. In section 5 I will discuss the findings from section 4 as well as the possible problems regarding the implementation of the proposed solutions. I will introduce a calculation model that can be used to optimise the routings. Finally section 6 will be the conclusion of the thesis, with in short some recommendations.

Section 2

Historical analysis

2.1 Containerisation

In 1934 a lorry driver in the United States of America called Malcom McLean set up a trucking company. In those days he sought for a standardisation of transport means, and came up with a standardised box, christened the container. It seemed to him a useful mean of transporting goods since he did not have to wait for loading and unloading of the lorry, but simply could pick up the load and leave, to drop it off at the destination. The ease of the container was not regarded by all drivers as a step forward. Many drivers saw the load they carried as their own and took pride in transporting the goods. The container was seen as a sterile entity that took away the spirit of trucking.

The major breakthrough came in 1956 when this same McLean set up Sealand. This company would not only use the containers for land operations but transport them at sea as well. Until then ocean going general cargo was transported in many different kind of packaging on general cargo vessels. The consignments were packed in barrels, in crates, on pallets, in cases, in sacs, in nets and in boxes depending on the nature. The ships would have several decks to store the goods and they were equipped with cranes to be able to handle the cargo on and of the ship. Loading and discharging the vessels sometimes took up several months depending on the nature of the cargo and the port of call. Because much of the cargo was not standardised, simple manual labour was the main mean of handling the goods. Although this long port time meant an enjoyable rest for the seafaring crew and abundance of labour in the ports, it was easily seen that the handling happened far from efficient.

This efficiency improved when the SS Ideal-X made her maiden voyage laden with 58 containers on April 26th 1956. To current standards, the efficiency is the late 1950's was not a real big revolution but compared to manual labour a huge step was made (Talley, 2000). This revolution however had a slow start before it really took off. It took ten more years before the largest port of the time, Rotterdam, welcomed its first containers. The SS Fairland arrived on may 3rd 1966 with a capacity of 226 containers. Because Rotterdam had no cranes to handle containers, the shipped was geared with cranes on its deck to be able to discharge the load.

The SS Fairland on the right, and a detail of the first unloaded container in Rotterdam on the left.

From the late 1960's onwards the container became a common mean of packing goods and container terminals rose like toadstools from the ground in many seaports. On the main transport routes, between North America and Europe, between Europe and Japan, and between Japan and North America, regular services emerged of dedicated container vessels. As trade continued to grow the number of ports, calls and services gradually increased. After the wave of globalisation that brought massive outsourcing and offshoring of production, especially to China and other East Asian countries, and the economical development of the less developed nations, world trade spurred even further, giving ocean freight, and consequentially container haulage another boost. Finally since the turn of the century many bulk products have found their way to container transport. These so called containerised neo-bulks have somehow blurred the separation between the different commodities handled in the port, as containers are not any more the exclusive domain of general cargo.

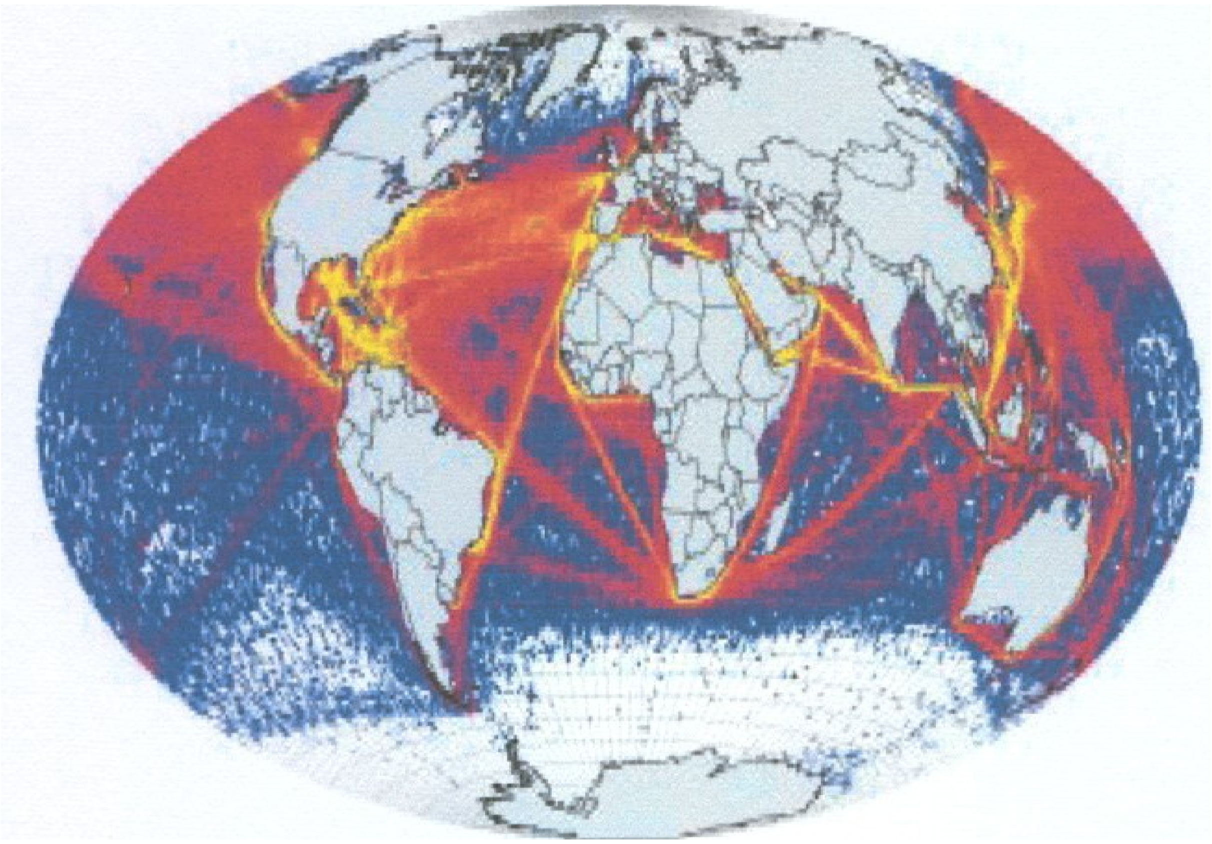
Logs loaded on a container, a typical application of neo-bulks in containers. Source Schiff & Hafen 10/2001 p. 10

With the gradual containerisation a whole new class of ships emerged. Along time the size of the container vessels increased dramatically, with each time larger and larger vessels to profit maximally from economies of scale in transport. In the ports these changes meant that terminals constantly had to adapt to the changes in the merchant fleet, as they had to follow all the alterations in ship design and their sheer size to be able to handle the cargo on and off the vessels. The physical and economical aspects of the ships have been important determinants in ship design. From a pure economical point of view one might say that the larger the better. This is due to economies of scale on the transportation part. There is however an economical limit to the ship size as larger ships take longer to load and discharge. The costs of this longer port time might offset the gains made in transporting more containers. On the physical side a number of restrictions have shaped the fleet. First of all the width of the Panama Canal of 32.2 metre has long been an absolute limiting factor on the size of the ships. Some carriers however chose to enlarge their vessels further, and rather sail around the Cape Horn or only operate between Europe and Asia. Besides the width, draught in ports and access canals is of great importance. The current largest vessels can for instance not enter all ports fully laden, the port of Antwerp which is the second largest port in Europe is a good example with draught restrictions on the Scheldt river.

For vessels the port time is increasingly becoming a major issue as time spent in the port is seen as unproductive, and sailing time as productive. Therefore the pressure is on the terminal operators to minimise the turnaround time, the time it takes from the moment the vessel enters the port till it departs again. To try to appease the carriers terminal operators had to try to achieve the same turn around time for the larger vessels as they previously did for the smaller vessels (Murty et al., 2005). Many terminals are therefore continuously looking for ways to improve their productivity especially through automation in order to keep up with the pace of change in the fleet.

Competition has always been fierce in shipping. This not only accounts for container traffic but also for liquid and dry bulks. The markets of bulk shipping and container shipping however are completely different. Bulk shipping is typically operated by small companies, without infrastructure, based on charter parties without a fixed itinerary, transporting cargoes of low values. Regarding competition bulk shipping has free entry and fierce competition. On he other hand, liner shipping is characterised by large companies with extensive infrastructure, based on bills of lading and sailing fixed itineraries, transporting mostly high value goods. On the competitive side, entry is limited and the structure is highly dominated by alliances and conferences, but still remains competitive.

Dry bulk ships are either chartered for a long time and serve on only one route between two ports or they are chartered just for a single voyage on the spot market and here too they will only connect two ports. In liquid bulk the market structure is similar, but because of the speculative trade in mainly crude oil, the cargo can change ownership several times during a voyage and therefore the final destination can change accordingly while sailing. Container shipping is organised completely different. Carriers or shipping lines operate regular services with a fixed time schedule.



Major shipping routes around the world.

These services comprise of a number of fixed calls, usually around half a dozen, along the route, and are generally run on a weekly basis. Worldwide two types of routes can be distinguished the major east-west trunk routes, and the north-south routes. By far the east-west routes account for the majority of the amount of containers transported. The north-south routes can be regarded as feedering from the main trunk. The geography of the container routes is influenced by both the location of production and consumption centres as well as economical purchasing power (Notteboom, 2004).

Competition in containers is fierce both between liners as well as between ports, and even terminals. This has to do with the so called footloose nature of the container itself. Because it is a standardised box, a container can virtually be handled by anyone with the right equipment. If ports share the same hinterland, thus making this hinterland contestable, a shipper can easily decide to switch ports of call for his containers if it makes him better off. Besides, a shipper of goods usually will not care about who handled the container and where it went as long as the destination is reached on time. Before containerisation, inland transportation and handling costs were relatively high ensuring a captive hinterland for each port. Developments in infrastructure and in transport technology as well as standardisation through containerisation have, especially in Europe, abolished captive hinterlands and increased dramatically the competition between the various ports.

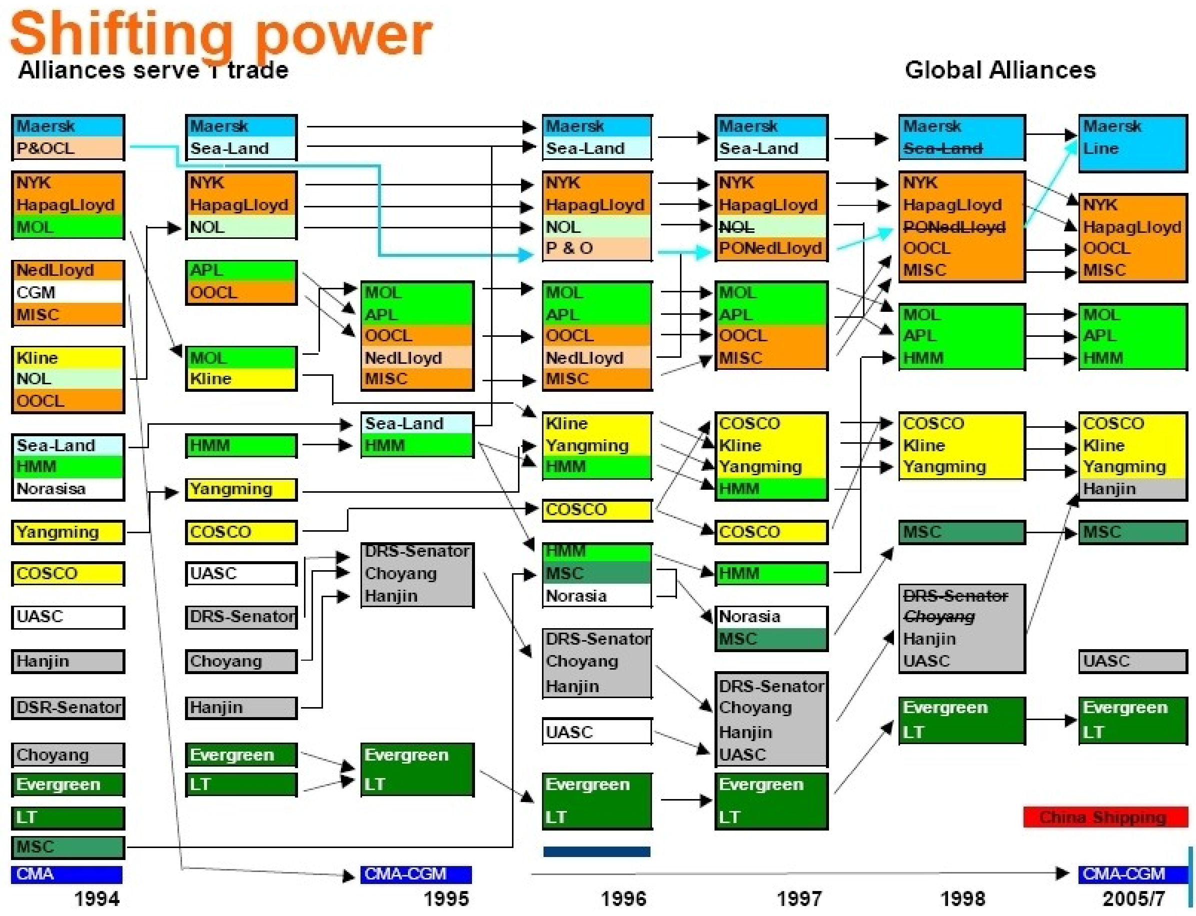
In the ocean haulage the competition between the liners is tense as well. For many shippers it is not important how and by whom the consignments are shipped, as long as the reliability of the transportation is guaranteed. Here again because of the standardised nature of the container and the fact that almost all carriers sail on similar routes, the competition is quite strong. To avoid a race to the bottom in prices, and therefore harm not only the competition but the entire sector, the major shipping lines have organised themselves. This organisation first occurred in the form of conferences, and later also in the form of alliances.

With the steam ships entering services in the second half of the nineteenth century, regular services and calls could be achieved. This sparked the beginning of the conference system that vowed a regular service. Liner conferences, established since 1875, were not different from cartels setting the prices for certain routes as well as controlling who entered the trade routes

(Sjostrom, 1989). Defecting from these fixed fares often resulted in the competitors preventing the vessel to moor or even put the defector completely out of business by always setting lower prices and sharing the lost benefit resulting from such action among the other conference parties. Although this form of cartel is forbidden in any other sector, the governments of the seafaring nations turned a blind eye. They valued the importance of the domestic maritime sector and the regularity of service higher than the monopoly power the liners obtained through the conferences. Other reasons to legitimise the conferences, are that they were meant to stabilise the freight rates and that the cost benefits would be passed on to the consumers i.e. the shippers. Although there has never been substantial proof of abuse of monopoly power of the conferences, they were eventually ruled as illegal by both the United States of America and the European Union, and had to be abolished for sailings to and from both trade blocks from October 2008.

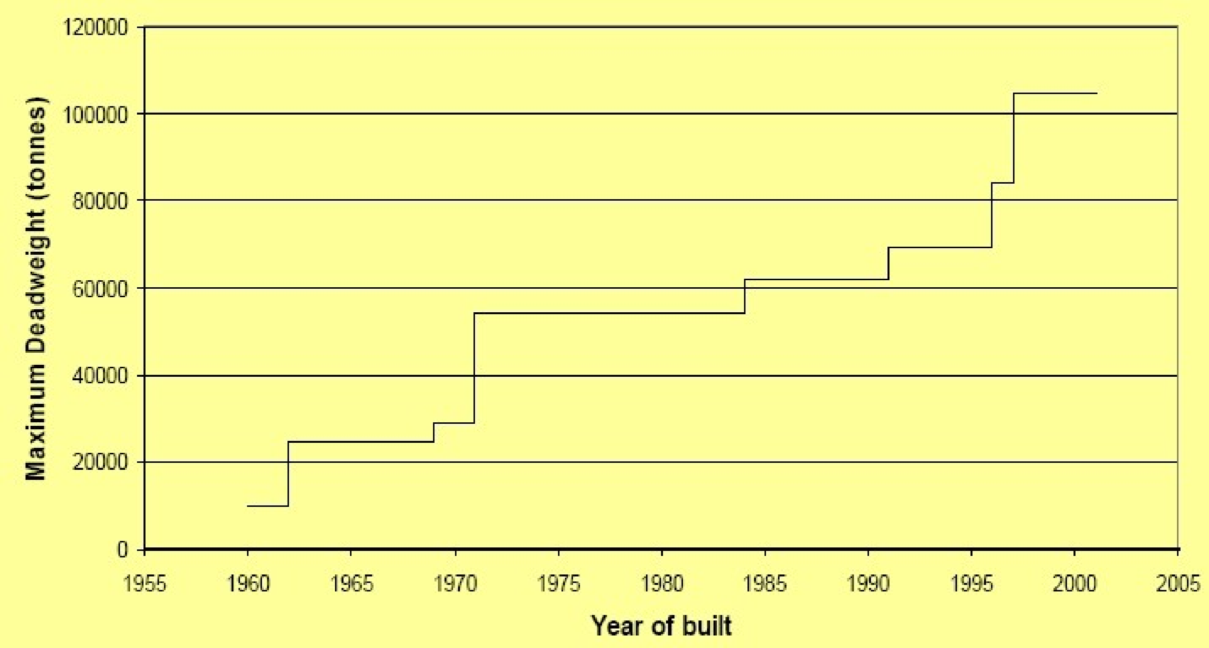
Next to the conferences a large number of carriers organised themselves in alliances. These alliances were set up for the same purpose as the conferences, namely to avoid competing each other to death, but had another trigger of emergence. The alliances started with the entering of low cost, mainly Asian, carriers into the market. The way the alliances are conducted is completely different from the conference system. In alliances liners cooperate in the field of complementing each others sailing schedules and routes. The main aim in this is to profit from economies of scale, and the fact that a critical mass applies to be able to maintain a regular service on certain routes (Sheppard and Seidman, 2001). This goes even to the point that they share slots on their vessels. This implies that if an alliance member has space available on its vessel to carry containers of another alliance member he will do so, expecting the favour to be returned by the fellow alliance member.

Nowadays cost reduction is the foremost goal of the alliances, and herein they seek to keep the frequent calling pattern and reliability. Some state that alliances have been even going so far as to commonly arrange order portfolio’s for new building of ships. This last would be in breech of anti trust laws, but has not been proven in practice. The alliances are often formed by liners with a common or similar history. Also can be seen that pure commercial firms and government owned carriers do not mingle. Continental background and size also play a role in the choice of partnership.



Changes in the container alliances of the world over time. Source lecture slides Ulco Bottema

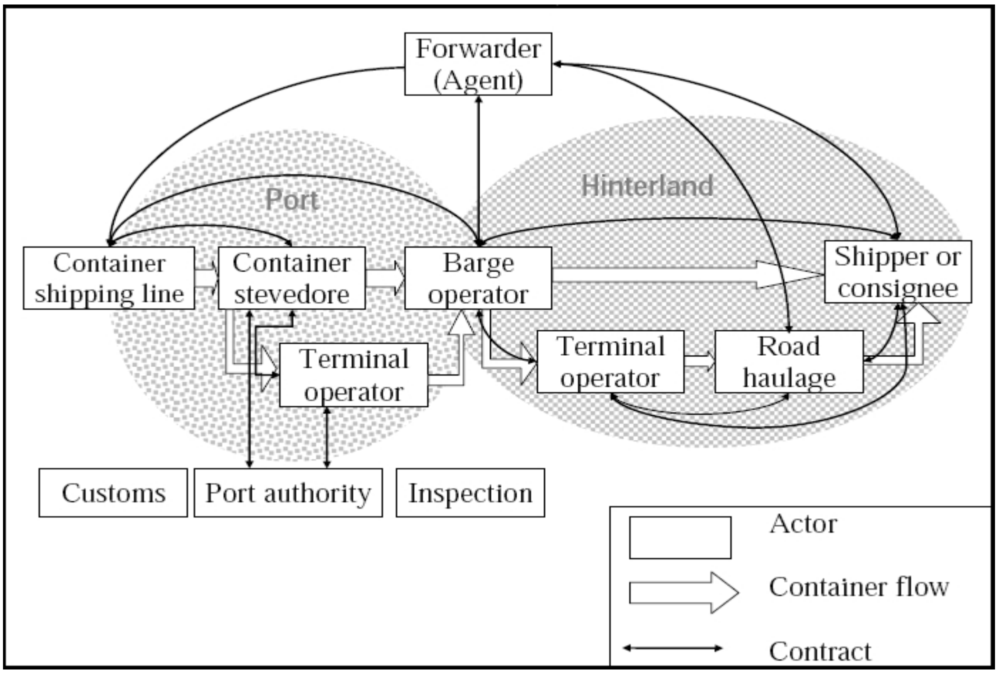
More recently, other measures have been taken by carriers in order to reduce costs and remain competitive. First, building cost and fuel cost reduction has been the target of acquiring larger vessels. Larger vessels are more expensive and do consume more fuel than smaller vessels, however per TEU (twenty foot equivalent unit, the standard measure of a container) both fixed costs and operational costs are lower than for smaller counterparts. Second, the services have been readjusted in such way that fewer ports are called at. Previously a liner could be visiting several ports within the same range, nowadays only one port would be frequented and the rest of the destinations within the range would be feedered from that port. This increases both the share of transshipment as well as the share of feedering or short sea shipping. Third, carriers tend to vertically integrate. This means that they attempt to integrate upward and downward the supply chain. This is mainly done by the acquisition or setting up of dedicated container terminals. In owning a terminal a carrier can make sure its vessels get all priority in handling. The intend is threefold, the transshipment capacity can always be accommodated, the turnaround time can be minimised and the schedule reliability can be improved.



Evolution of container ship DWT over time. Source Shipping Innovation, Niko Wijnolst & Tor Wergeland.

Container shipping can be divided into two different types, carrier haulage and merchant haulage. When the carrier solely takes care of the sea leg the transportation is referred to as merchant haulage. It is called merchant haulage because the merchant or shipper or simply customer has to arrange for the hinterland part of the transportation. Carrier haulage is when the carrier takes care of the entire transport, both ocean and hinterland connections, from door to door as it is called (Notteboom, 2004). The main difference of the two types is seen in the contractual relationship between the liner companies, the shipper, the terminal operator, and the hinterland connection operator (for example barge operator).

The carrier contracts the deep-sea terminal operator. In this contract all other arrangements are made concerning further transportation regardless the type, by transshipment (onto feeder or other deep sea vessel) or by hinterland modalities road, rail and barge. The hinterland operator, for this example the barge operator, is contracted by either the shipper, in case of merchant haulage, or the carrier, in case of carrier haulage. In all cases however there is no contract what so ever between the terminal and the barge operator. And in this lack of contract lies a major obstacle in the problem with hinterland transport (De Langen & Van der Horst, 2008). The barge operators do not pay for the handling of their containers, nor is there an opportunity to sanction each other from both ways in case of breeching an agreement, such as a time window, or dissatisfactory handling.



Contractual relationships in barging. Source De Langen and Van Der Horst, 2008.

The tendency from the carriers’ point of view is to increase the percentage of containers that are shipped on a carrier haulage basis. There are two main reasons for this. First the hinterland transport costs often account for the majority of the costs incurred in the entire transportation of a container. This does not automatically imply that there is a lot to earn from this leg, as when carriers would charge higher rates, merchant haulage will take over their share. However it can be a prospect to reduce the total transport costs. Second in moving into hinterland transport, the carriers can gain insights in the whereabouts of the containers, and have more control over them. The majority of all containers are owned by the major shipping lines. The repositioning of the empty containers is always a difficult and costly task because the locations are often unknown (Shintani et al., 2005). The large increase of inland terminals does however counter this objective because it becomes increasingly difficult to trace all containers and acquire information about their dwell times.

To explain the figure but also the rest of the thesis, I will shortly focus on the most important actors that play a role in the supply chain.

The shipper or consignee is the normally the owner of the shipment, but can also be the one for whom the freight is destined or the originator of the consignment. The shipper is basically the key person in the chain, or even the reason for the chain’s existence.

The freight forwarder is specialised in organising the entire shipment. These companies are well connected with the other parties and usually shipping goods via a forwarder is cheaper than arranging transportation yourself because of package deals and freight consolidation that the forwarder can achieve. In fact the freight forwarder operates on behalf of the consignee and makes sure he gets what he wants.

The carrier or liner shipping company is responsible for the ocean leg of the transportation. These liners operate fixed scheduled routes and often own the boxes used in the trade. The recent trend is that the carriers vertically integrate and take over parts of one or more of the other parties (Robinson, 2006). This is especially seen in the ownership of terminals both in the seaports and in the hinterlands.

The deep-sea terminal operator is the operator that handles the sea going container carriers. The operator often owns the terminal in the seaport. Next to the handling of the ocean going vessels, the terminals provide the possibility of temporary storage at the facility and are also responsible for the transshipment of the containers be it to other sea ships or the hinterland modes road, rail and barge.

The barge operators are the companies that arrange the hinterland transport by barge. These operators often do not actually barge themselves but contract barge companies. The barge companies are the owners of the vessels and they sail on the vessels. In general the barge operators contract the barge companies for a fixed period, for example for a year, and often they have such contracts with several barge companies.

The inland terminal operators are the companies that operate inland facilities that are used for the modal split of containers from the barges towards rail or and road and vice versa. Like the deep-sea terminals they often provide container storage and are also used for transshipment from barge to barge. These inland terminals are usually located on spots where waterways intersect or meet other infrastructure, and not necessarily in large residencies.

The truck operator is the company responsible for the container transportation by lorry. Because the end customer or the originator of the freight are normally not located in the immediate proximity of the inland terminal, almost all container journeys, although transported by barge, will originate or end up with a leg by lorry.

The custom department is present in all seaports and its task is to inspect the cargo as it enters or leaves the country. Its importance for the chain is rather low although all containers should be cleared by customs. However if the 100% check that the United States of America wants to introduce for containers bound for or coming from the USA, which is according to me both impractical and useless, will eventually be implemented, customs could become an significant source of delay in the transport chain, and thus can grow in magnitude.

The port authority finally, has a number of tasks. First, it is the owner of the land on which the terminals and other facilities in the seaports are built on, this is leased out to the various operators. Second, the authority is responsible for the infrastructure within the port. Third, the port authority has to ensure the safety on the waters in the port and has to manage in port traffic in an efficient way.

2.2 Inland transport

The first containers to and from the ports were transported by lorry. In ports with railway links, the containers soon found their way onto rail carriages especially for long inland hauls. Barge shipping only took off later. In the early days it was not seen as competitive to the other modes since the final destination could never be reached by barge. On top of that, the competitiveness of barge transport would only be beneficial in case of large numbers.

Inland shipping or barging of containers is relatively new compared to both inland bulk shipping and ocean going container transport. The major arguments for this is the lack of navigable waterways in major parts of the world, the competitive position of barging compared to the other modes notably road haulage, and the critical mass that is required to make barging economically viable.

Intensive use of barges for inland container transportation has really fostered on just four major rivers in the world, the Yangtze in China with Shanghai and Ningbo as major seaports, the Pearl River in China with Guangzhou, Hong Kong and Shenzhen as major seaports, The Mississippi in the United States of America with New Orleans and its subsidiary ports as major seaport, and finally the Rhine in the Netherlands and Germany with Antwerp and Rotterdam as major seaports serving the hinterland.

A 2007 study by Theo Notteboom reveals remarkable similarities in the development patterns of the Rhine and Yangtze container barging history. Like the Rhine, the Yangtze River can be parted in three segments with their own distinct features. The developments were such that the lower Yangtze was the first to see inland navigation on a large scale. Due to outdated equipment and poor navigable qualities, it took quite a while before the middle Yangtze and the upper Yangtze were used extensively. But now with growing throughput volumes the convergence with developments on the Rhine, although with a time leg, is clear. On the Yangtze, there is a dominance of line bundling, with hardly any multi-area bundling, compared to no multi area bundling on the Rhine. The average number of calls per rotation varies from three to four for the Yangtze and from three to five for the Rhine. The expected growth rates are moderate for the Rhine and strong for the Yangtze. Finally the river hub position of Duisburg can be compared to the present function of Nanjing and the possible future function of Taicang. (Notteboom, 2007a).

2.3 Rotterdam

Because this thesis focuses on a Rotterdam problem I will give a short summary of historic developments the port of Rotterdam went through.

The port of Rotterdam is located on the North Sea and is a year long ice free port. It is strategically located at the estuary of the river Rhine, which shares its delta with the river Meuse. The initial port of Rotterdam dates already many centuries back, but the first contours of the modern port were established around 1920. Until then the function of the port was one of a pure urban port solely serving the city. After 1920 the port started its development with new activities. The Waalhaven was erected and some petrochemical industry was established.

After the second world war during which the port was completely destroyed, the port rapidly recovered as Rotterdam became one of the main gateways for the Marshall plan which consisted of a massive help package from the United States of America for its new European allies. At that time the Botlek area was opened, quickly followed by the Europort area and later the Maasvlakte which was reclaimed from the sea.

To accommodate the port more westwards several residential areas had to be demolished and built elsewhere which spurred protests among the local population. Furthermore the port had to deal with ever stronger environmental concerns as the port activities especially from the 1960's to 1980's were far from clean. Despite these setbacks the port continued to grow and was for long the largest port in the world. It still is the largest port outside Asia regarding throughput in tonnage. Rotterdam is connected to more than 1000 other ports through over 500 lines, and stretches over some 40 kilometres. It has a surface of more than 10000 hectares which will be further enlarged with the finishing of the second Maasvlakte that is currently being reclaimed from the sea. The directly generated employment of the port amounts to around 75000 workers[1].

The port of Rotterdam is also the largest container port of Europe in number of handled TEU's. On the world scale Rotterdam ranks 9th in terms of TEU's[2]. In Europe, the leading position regarding total throughput is unreachable for the main rivals in the near future. On the container market the lead in Europe is increasingly under threat, although Rotterdam has topped the standings since the introduction of the container. The main rivals Antwerp and Hamburg have managed to gain market share at the expense of Rotterdam in the last two decades. Because its hinterland almost entirely overlaps with Rotterdam's, Antwerp can be considered as the major competitor (Loyen et al., 2003). Rotterdam's main advantage over its close rivals remains the larger draught it can ensure for incoming vessels, and its well developed hinterland connections, that comprises of a good network in all three modes especially with the recent opening of the Betuwe railway line. The proximity of the ports in the Hamburg – Le Havre range, with the many competing container terminals makes competition in north-western Europe one of the most if not the most fiercely battled grounds.

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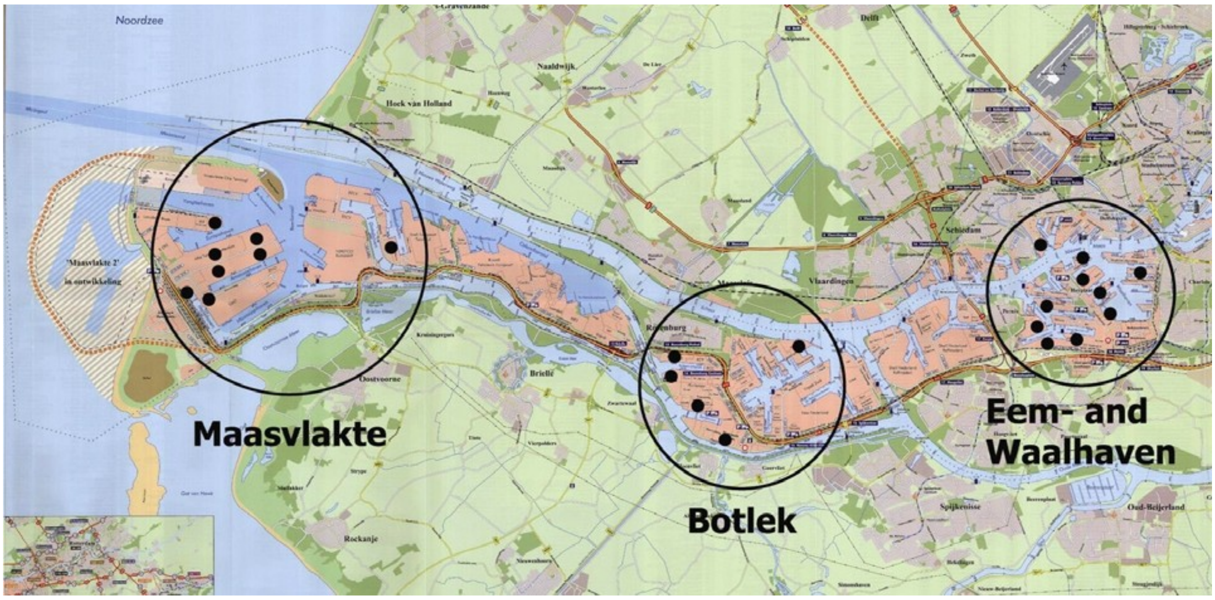
[1] All numbers from the Rotterdam port authority

[2] Figures from 2008 source ISL

According to the Rotterdam port authority a change of power balance is expected (Gemeente Rotterdam, 2004). Most likely the future will bring a further increase in scale, with fewer global liners that divide the container sector. The expectations are that those liners will more and more integrate vertically into the supply chain and become important players in ship and terminal ownership, to better control all links in the chain of connections. Thus the competition will shift from terminals and ports to entire competing networks. Rotterdam will most probably become a link in these networks, according to the port authority, and the vision is to remain the leading player in Europe. Indeed the footloose character of container transport does not imply automatically that the current position can be maintained. Furthermore, customers might depart from the port not only because of inefficiencies or lack of proper infrastructure, but also because of newly formed partnerships or network alliances (Slack et al.,1996). An illustration of the mighty influence of alliances and networks is the usage or rather the lack of usage of the Ceres Paragon container terminal in the port of Amsterdam. This state of the art terminal built in such a way that vessels can be discharged and loaded from both sides remained unused in first five years of operations because ownership of the terminal switched to an alliance that preferred sailings to Rotterdam and therefore left the terminal completely empty for the first few years.

In order not to lose out on the rivals Rotterdam has to try to differentiate itself from the competition (CBRB, 2003). To achieve this, the focus should be on the accessibility of the hinterland, and maybe even more important on the reliability, the cost-effectiveness and the transit times of these hinterland connections (Visser et al., 2007).

Due to the gradual westwards growth of the port in time, the main container terminals are located in three distinct clusters. The cluster positioned the closest to the sea is the Maasvlakte which is currently undergoing a widespread expansion. This cluster has the largest capacity of the three and is frequented by the largest container vessels, the so called very large container carriers or VLCC in short. The cluster located a bit more eastward is the cluster in the Botlek area. This cluster consists of mostly relatively small terminals and empty container depots. Finally the oldest and more easterly located cluster is the Eem-Waalhaven cluster of terminals.



Map of the port of Rotterdam with the black spots as main container terminals. Source port authority Rotterdam.

The Eem-Waalhaven cluster nowadays handles the majority of the short sea shipping. The outstretched character of the port is responsible for long travelling times between the different clusters and terminals. Sailing from one end to the other can take up to three hours for a barge, and from one cluster of terminals to another can easily take between one or two hours while the different terminals within the clusters can be reached in about twenty minutes. In total the port of Rotterdam is home to some 37 terminals and empty container depots.

The barging market from and towards Rotterdam can roughly be divided in three different segments. First, there is the barging between Antwerp and Rotterdam which accounts for around 1 million TEU, second, there is the barging on the river Rhine with roughly the same amount of containers, and finally the domestic barging with other origin or destination then the previous two 700,000 TEU but rising (all figures for 2004)[3]. This distinction can be made because of the different organisational structure of the diverse sailings.

The trade between the seaports of Antwerp and Rotterdam is the consequence of the call patterns of the carriers. In order to cut down on port time carriers increasingly make the strategic decision to solely call once or maybe twice in the same port range. Because of the proximity of the ports of Antwerp and Rotterdam, often only one of the two ports is called at. If a container is to be transshipped from the other port, this container has first to be transported from the first to the second port. Although some of this cargo is moved by road

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[3] Numbers from Konings, 2007

transport, by far the largest amount of these containers goes by barge between the ports of Antwerp and Rotterdam. The amount of terminals frequented is relatively low and therefore the call sizes of these barges are typically high. The sailing takes place over the Scheldt-Rhine canal and takes around twelve hours. Almost all of this trade is carrier haulage, and this route is also widely used to reposition empty containers. Since carriers usually have possession of the containers, they prefer to transport their own boxes, and therefore exchange empty containers amongst themselves.

The domestic trade is relatively new in the already young history of container barging. When the shipped volumes were not as high as nowadays, one thought that barging would not be able to compete with the other two modalities road and rail transport. The mindset behind that was that because of the high fixed costs involved, one cannot profit from barging without taking advantage from economies of scale. These advantages could only be there if either the distance to be covered would be extensive enough, or that the sheer amount of containers would be such that economies of scale would occur. Until the beginning of the 1990’s the needed critical mass in containers was not reached yet, making barging not competitive with the other modes. With growing trade and containerisation on the rise, domestic barging flourished with the emergence of numerous inland terminals within the Netherlands. Some of these terminals are operated by companies that both are barge operators and terminal operators. The domestic trade is mostly characterised by merchant haulage.

Company	Sailing area	Volume in 1000 TEU's	Number of own barges
Rhinecontainer	Rhine	375	18
HTS	Rhine, domestic	340	32
CCS	Rhine	330	14
Imperial Reederei (Haniel/Alcotrans)	Rhine	200	10
DECeTe	Lower Rhine	160	4
Danser	Rhine	150	8
CEM (Rhinecontainer)	Antwerp	140	4
Lucassen	Antwerp, domestic	140	5
Eurobarge (Danser)	Antwerp	140	4
Interfeeder Ducotra	Rhine	100	4
Haeger & Schmidt	Rhine	80	4
Rhenus Alpina	Rhine	75	4

Most important barge operators in the Netherlands in 2003. Note that the number of owned barge does not really matter as most operators hire capacity. Source Sectorverkenning Combinatievaart, Rabobank 2004.

2.4 Rhine barging

The Rhine barging has actually been the cradle of the other types of barging. Its history goes back to the late 1960’s. The next section will deal shortly about the different stages in barging in north-western Europe with emphasis on the Rhine container transportation.

As barging is a form of hinterland connections, its characteristics are highly dependent on the fluctuations and developments in deep-sea container transport. Furthermore, the network of inland connections is a derivative from large supply networks that mainly focus on the large ocean trunk routes. Barging in Europe mainly started around the Rhine River and its two main feeder ports Rotterdam and Antwerp. Later in time, based on the Rhine trade, as the transported amounts gradually increased, a vaster network of inland terminals emerged in the entire Benelux and northern France.

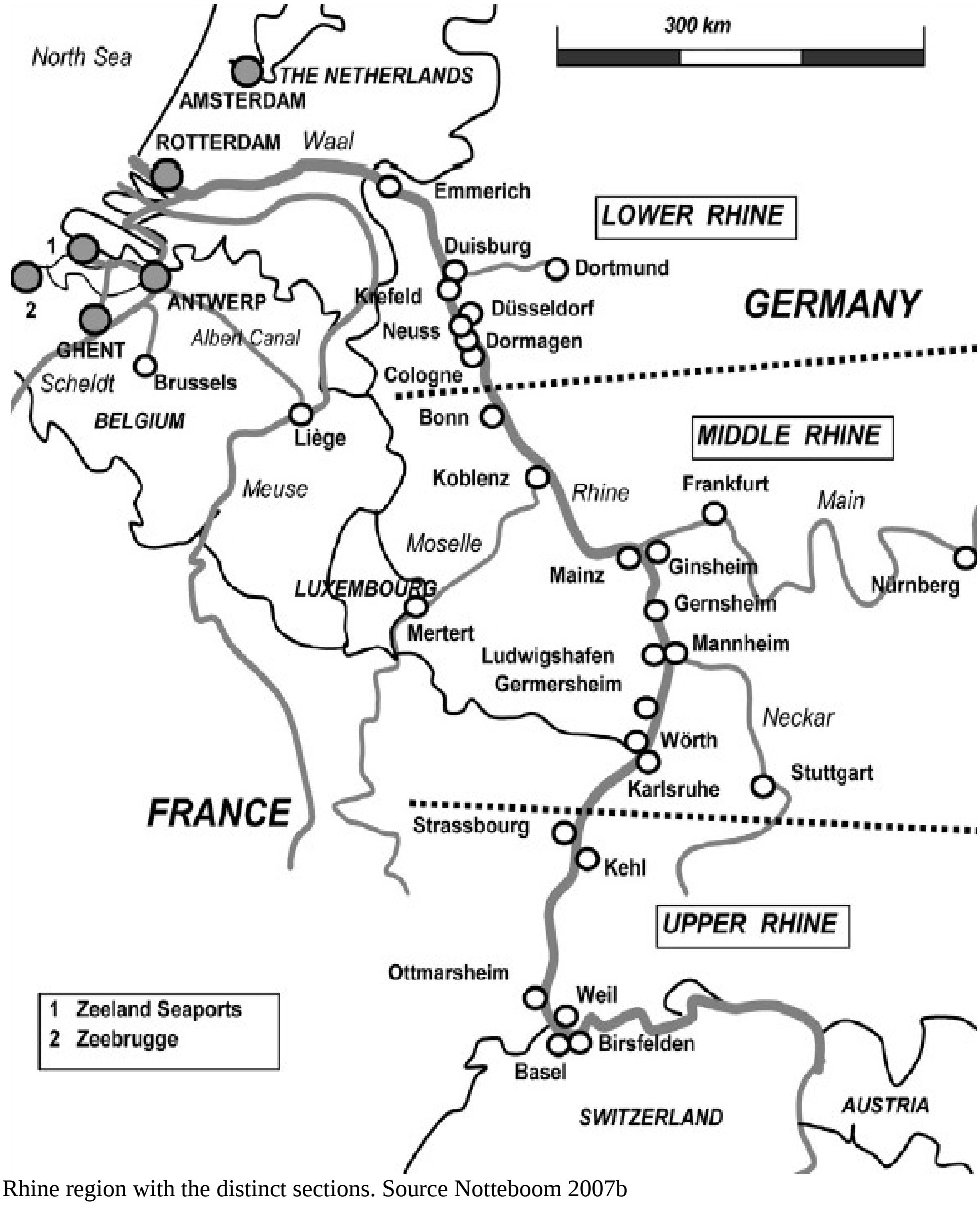
Historically four different stages can be identified that have shaped barging in north-western Europe. These differences are found in the size of the barges, the type of terminals, the type of services, and the entire organisational structure behind them (Notteboom, 2007b).

The first phase is the very first beginning of barging in Europe from 1968 to the early 1970’s. The throughput over the Rhine did not exceed 10000 TEU’s per year until 1975. Most transports were conducted by adding containers on normal, non-dedicated, barges. The call sizes often comprised of just a few boxes and they were shipped in irregular services. In those times container transport by barge was only seen as competitive with the other modes of transport, road and rail for long haulages over 500 kilometres. Therefore the only services that were conducted were from Rotterdam to the relative far destinations of Mannheim, Karlsruhe, Strasbourg and Basel. In the beginning the containers were shipped to conventional terminals. Mannheim was in 1968 the location for the very first inland container terminal, shortly followed by terminals in Basel and Strasbourg (Van Driel, 1993). A small number of players was active on the barge operator market as the popularity of the mode was not really establish because of the fact that transshipment and the transport from the barge terminals to the end users was not included in the package provided.

The second period in barging is from the mid 1970’s to the mid 1980’s. In this period ocean going transport of containers to Europe increased dramatically. The organisation of the sea routes developed to the point that carriers concentrated their traffic to a limited number of seaports. The high volumes in those chosen ports on their part created the necessary critical mass in terms of number of TEU’s to ensure a regular flow of containers to the major inland locations. Therefore more terminals appeared both in existing ports as newly built facilities, and the higher volumes enabled a regular scheduled service to the inland terminals. The Rhine market has been divided into three distinct parts: the lower Rhine from Rotterdam to Cologne, the middle Rhine from Cologne to Karlsruhe, and the upper Rhine the remainder of the navigable part of the Rhine from Karlsruhe onwards. The Mosel, Neckar and Main, rivers that all flow into the Rhine, are to be considered as part of the middle Rhine section. The barging market was split up by a small number of actors that subjugated the market. In order to gain full control over their own market share, these large barge operators have set up their own terminals along the Rhine. Next to those single-user terminals, a small number of common-user terminals have emerged during the 1980’s that welcomed containers from all operators.

The third period, from the mid 1980’s till the mid 1990’s, saw a further increase of container volumes on the Rhine. Characteristic for this stage is the fact that a number of container facilities were also set up on the lower Rhine, and not only on the upper and middle Rhine that had been the main destinations during the previous two stages. The reason for this was that before this stage the competitive advantage of barging was only seen for distances over 500 kilometres due to the fact that the fixed cost components that are connected to barging comprise a comprehensive part of the total costs. To profit from economies of scale large haulages were needed to cover those fixed costs. With increasing volumes however, these economies of scale could also be met because of the sheer volumes involved.

This third stage saw also the surfacing of the so called Fahrgemeinschaften, a type of alliance very much alike the cooperation amongst the ocean carriers. These alliances were primarily set up to avoid a destructive form of competition that could lead to a race to the bottom. Therefore in all three zones of the river, operators would cooperate in joining services within the alliances. The basis of this collaboration was that all operators would preserve their own identity and commercial autonomy, but work together in sharing some information, and thus combining the services in such manner that the load factor would be optimised. The collaboration was not only born out of efficiency reasons alone but also out of pure necessity as most Rhine carriers were operating under their marginal costs and consequentially were losing money. The partnerships proved to be successful as most operators were back in black by the mid 1990's. A side effect of the alliances was that because the operators would work together, they could schedule their departures in such ways that the regularity, the punctuality and even the frequency of their services, especially on the lower Rhine improved significantly.



Map of the Rhine region with the distinct sections. Source Notteboom 2007b

The fourth phase in the Rhine container transport is from the mid 1990's till today. The main feature of this period is the appearance of inland terminals outside the Rhine basin. New container terminals have been set up on the rivers Rhone, Seine and Elbe. On the Rhine the density of the terminal network grew more and more as well as the number of terminals in immediate proximity of the main seaports. A number of terminals, notably in Germany have been put up vowing to combine rail and barge operations. The purpose is to transship containers from barge onto the railway system in location such as Dortmund. This form of transshipment has however not materialised (yet) due to low container volumes destined for this type of modal split. In some other locations the trend is opposite as the number of terminals is dropping on certain waterways. The reason for this does not lie in the number of boxes shipped, but it is caused by the fact that a number of terminals was set up with subsidies to encourage the local economy and proved not to be economically viable when the subsidies diminished. From the operators' side the tendency was to centralise the barging to just a few terminals in contrary to the period before where decentralisation was the approach. The concentration of traffic, especially strong on the middle Rhine section spurred the introduction of larger barges up to 400 TEU's on the river. In pure numbers this fourth phase shows again consistent and strong growth of shipped boxes. The number of TEU's transported over the Rhine doubled from 650000 in 1994 to 1300000 in 2002. These numbers are more or less equally split between Rotterdam and Antwerp, and roughly half of all traffic is bound for the middle Rhine section. The fourth period also brought considerable changes in the operators' alliances on the river. As the volumes kept growing a number of independent operators started to enter the market. Even some bounded partners left the existing alliances because things were going so well that they thought of being better of on their own.

During the third phase the main alliances were set up. These are a few examples of the most prominent ones. On the upper Rhine the Fahrgemeinshaft Oberrhein (OFG) consisted of Rhinecontainer, Interfeeder Ducotra, Haeger & Schmidt and Haniel Container Line. On the lower Rhine, Haniel Container Line, Haeger & Schmidt, Rhinecontainer and CCS set up the Fahrgemeinschaft Niederrhein (NFG) (Notteboom, 2007b).

Container terminals in the Netherlands close to the main seaport, new trend in the fourth phase. Source map BVB

2.5 The current situation

On the Rhine, currently, in each of the three different sections the barge services offered call at three to six inland terminals. This amount is such to obtain a reasonably good load factor on the barges and still maintain a frequent and regular service. The services on the lower Rhine are usually sailed twice a week, on the middle Rhine the frequency is around once a week and on the upper Rhine the services are mostly scheduled for once every two weeks. In the terminals the waiting time for barges averages around an hour. That efficiency is not met by the number of calls in the sea ports that on average can amount up to ten calls or more. This great amount of calls in the seaports causes substantial delays and congestion at the terminals. Terminals have no contract with the barge operators, and therefore will give priority to sea going vessels with which contracts do exist, at the berths. Barges that have many calls to make in the port will consequentially miss out on one of the early appointment windows, and will therefore not be able to meet any of the following either. The result is that barges often spend several days in the seaport before they are entirely discharged and reloaded. For the port both the delays as well as the great number of moves within the port cause coordination problems regarding congestion especially taken into account that the numbers of containers are still expecting to grow further even in spite of the current temporary drop due to the economic crisis.

The average calling pattern in the seaport is arranged as such that barges have to stop at many different terminals to discharge and load the ship. This means that a lot of time is spent in port. The voyage time between the various terminals accounts for a part but especially the waiting time at the terminals themselves before being handled is an important determinant for the port time. The actual discharging and the loading of the barges are pretty well managed and at around twenty moves per hour, it is done quite efficiently. According to Rob Konings, barges on average only spend around 60% of their time sailing, and 10% at the terminals. The remaining 30% is used in the port for sailing between the terminals or is wasted waiting in the port (Konings, 2007).

The average call size shows quite some imbalance. Half of the calls made in the port are to load or unload six boxes or less (Konings 2007). The smaller call sizes are usually made in the Eem/Waalhaven area and the Botlek area, the larger calls are in general made at the terminals on the Maasvlakte. These small calls make the port time a lengthy stay, especially if delays occur on such small calls. A delay at one terminal can have far fetched consequences. In order to limit waiting time, barge operators often make appointments with the terminals. Typically a time window is agreed upon within which a barge has to arrive and can be served. If a delay occurs and the time window cannot be met, the delay will also affect the next appointments for both terminals and barge operators, and these for appointments thereafter, and therefore effectively contaminate the whole appointment system. As mentioned before, there is no contractual relationship between the barge operators and the terminals. The lack of such relationship does not contribute to efforts to make the time windows at all costs. Notably terminal operators are known to give only last priority to barges for berthing space as such contracts do exists with seafaring vessels which are therefore prioritised.

The delays and long waiting times are not only a problem for the barge operators. The port itself suffers from the delays as well. Currently of the 165000 moves made on water in the port some 130000 are accounted for by barges[4] the rest by sea going vessels .With these numbers congestion on the water might become a serious problem. It can easily be seen that delays can cause further congestion next to issue of the actual space a waiting vessel takes up. Furthermore, the delays can affect the reliability of the hinterland connection of Rotterdam. If the sailing schedules cannot be guaranteed, consignees might be tempted to look for another port to ship the goods through. Thus, the delays in the port can easily affect the competitive position of the port as a number of customers could switch to a competitor.

In the quest for more sustainability, the modal split of barging in hinterland transport has grown in importance this last decade. The underlying reason is the societal trend towards cleaner and more sustainable transport concepts, notably in Western Europe. Both rail and barge transport are seen as acceptable alternatives for road transport for two main reasons. First, both modes are cleaner i.e. the emission of pollutants are lower per tonne kilometre than road transport. Second, rail and barge do not make use of the roads where congestion is becoming a major concern around the larger port cities as well as on the main road arteries towards the hinterland. Therefore barge transport has become more and more the focus of policy makers. An illustration of this is the fact that for the major expansion of the port of Rotterdam, the second Maasvlakte. The terminal operators based there signed a covenant in which they voluntarily strive for a larger share of rail and barge in the hinterland transport from and to the terminals.

Container transport in general is expected to rise further the coming few decades in spite of the current lull. The goal in Rotterdam is to remain the main gateway for the European continent and especially for the economically important Rhine and Ruhr area. If so, the container throughput in Rotterdam will rise considerably the next decades. Indeed on the seaside a major expansion takes place with the building of the second Maasvlakte. This part will be home of several container terminals. With both the amount of containers growing and the share of barging within the hinterland transport growing as well, the current situation is not apt to deal with barging properly.

The organisational structure of barge transport as well as the freight consolidations on board is the results of efforts to optimise the hinterland logistics, and the calling patterns have

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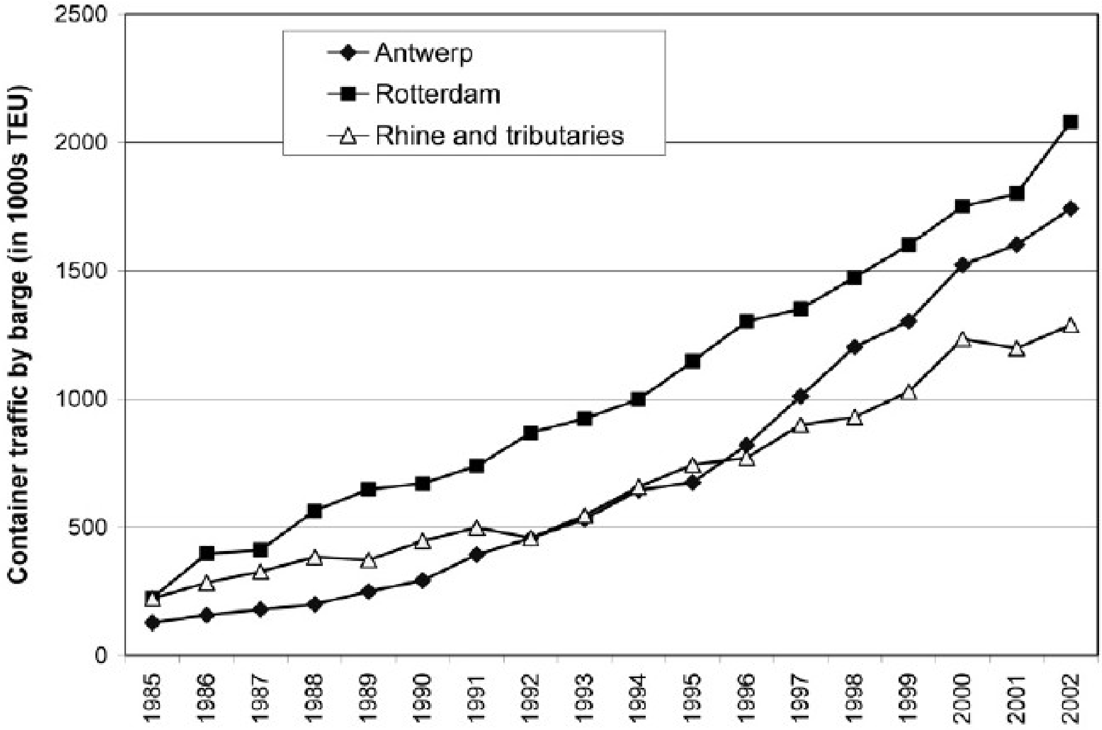
[4] Rotterdam port authority

changed little the last decade or so in spite of augmented volumes. In the gateway seaports the picture is totally different. The number of calls went up and the turn around time increased dramatically. The current situation leads to a sub-optimal solution for the entire chain because the cost structure and call patterns that have not changed over the years.



Container growth on the Rhine and in the ports of Antwerp and Rotterdam. Source Notteboom, 2007b.

Section 3

Literature review

3.1 Seaports

Globalisation and the steady increase of trade volumes have changed the shape and function of the traditional ports. Integration of economies world wide, but especially in large trade blocks such as the European Union, amelioration of transport facilities and modes, new communication technologies, and further emphasis on the logistics behind the transport chains are all elements that have contributed to these changes. Thus resulting in a different position of the ports towards the hinterlands. The borders of the exclusive or captive hinterlands have blurred if not disappeared all together, and ports are now more and more in mutual competition (Haralambides, 2002). The following overview will in short show the dynamics in the changes over time, as well as pointing out how some leading scholars view the position of ports within the competitive framework. The main focus will be towards hinterland connections and derived from it the major obstacles therein.

Robinson argues that port functions have shifted from the traditional gateway perspective to a more embedded entity within the larger supply chain. Reasons for this change are found in the fact that not only ports compete with each other any more, but entire transport chains are in fierce competition for the shipment of goods. This again is the result of vertical integration within the supply chain in which the various functions (shipping line, shipping agent, stevedore, custom agent, freight forwarder, depot, hinterland operator, etc.) are increasingly taken over by one single party enabling this party to profit from economies of scale and control within the chain. Herein the position of a port is to deliver added value to the shippers and third and fourth party logistics providers. In other words, ports not only create value for themselves, but on a much higher plan they contribute value to the whole chain in which they lay. Robinson talks about a new paradigm in which the port authorities are involved as they have to strive for locations within those larger supply chains (Robinson, 2002).

On the same path Jacobs and Hall have researched how individual port actors are able to settle themselves within the larger supply chains. Their empirical work has looked at the emergence of Dubai Ports World as a major global player. They show that the strategy regarding decisions made by the port actors are driven by the institutional framework that characterises the local or territorial way of operating. They identify a number of key factors that play a role in this decision making. According to them “place specific and path dependent physical, institutional, and political factors underlie the territorial embeddedness which enable or constrain the supply chain related strategies of port actors”[5]. The empirical study shows that indeed Dubai has managed successfully to settle itself within the larger global production networks using the specific local way of conduct (Jacobs and Hall, 2007).

Hinterland access is by many seen as a vital part of the competitiveness of a seaport. Already in 1963 Taaffe et al. developed a model regarding network development. Although their empirical analysis is focussed on the coastal region of Ghana and Nigeria, the establishment of the network in phases as showed by them is regarded to be typical for almost any port development, but often more spread over time. They recognise four different phases. The first being a phase with scattered ports along the shore line. These port have no overland connection and all serve a distinct hinterland. In the second phase the first changes appear, with so called penetration lines land inward and concentration of port activities in some of the ports. This concentration continues over time with some initial ports disappearing completely and others growing at their expense. In the third phase land connections between the ports begin to evolve and some ports become dependent on the feedering from other larger ports. In this phase the hinterlands start to overlap with the major ports gaining share in initial captive hinterlands of other locations. The fourth phase engulfs the high priority linkages as the authors call them. These are dominant hinterland routes of both rail and major roads. The linkages connect important large residential and industrial centres to the ports. The new linkages come first where the largest centres are located. But with better connections these centres have a growth advantage over others and therefore grow faster, with a need of even more connections. This shows that developments in hinterland connection can be path dependent (Taaffe et al., 1963). This path dependency is indeed also seen in the developments of the major ports in Europe. Rotterdam is a good example of this mutual causation. With the development of the Ruhr area came more transport through the port. The growth the port experienced, placed it at the preferred location for more users needing a gateway. This again ensured further growth in the hinterland, leading again to enlargement of the port.

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[5] Jacobs and Hall, 2007 p 339

Another famous model used by scholars is the model constructed by Bird. The anyport model depicts the development of the port over time with a higher degree of integration the more the time elapses. In the first stage the port uniquely serves the city around the port, this is the setting stage. The second stage, expansion takes place with a growing hinterland and a few connections to this hinterland and overland linkages with neighbouring ports. In the third stage the port goes through specialisation to better serve a growing hinterland. And finally in the fourth phase the port becomes a more regional port serving a large hinterland with several inland terminals and distribution centres along the major hinterland connections (Bird, 1980). According to Notteboom and Rodrigue, the model is incomplete or at least has its limitations as it cannot provide the base to explain the emergence of hub terminals in island or remote locations with small or even absent hinterland and hinterland connections (Notteboom and Rodrigue, 2005). This causes the latter ones to state that size and hinterland activities are not included as driving factors in port development dynamics. According to them hinterland accessibility is more and more the prime issue in port competition. This is illustrated by the footloose character of container throughput in ports. Easily a shipper can switch to another load centre if for example congestion in hinterland modalities may hamper reliable expedition. Also carriers may chose for different ports of call if they would fear losing out to rivals as they serve better connected ports.

Slack, in his article about the emergence of inland load centres, adds another stage to the model proposed by Taaffe et al. In this phase he indicates that when maturity is reached in intermodal hinterland access, inland terminals not lying on the larger and more important routes will become obsolete and therefore will disappear over time again. Concentration of trade is a trend that will continue according to him. He clearly sees winners and losers from further concentration of trade, and therefore according to him it is essential to obtain and maintain a position on the most important transport axes (Slack, 1990).

Barke as well has put up a similar model to the one proposed by Taaffe et al. He comes up with a model consisting of five different stages. The major addition to the original model is the introduction of a phase wherein deconcentration occurs. According to him this happens when a port and its area goes through a phase of rapid growth and through that process gets congested. The result is that port activities may develop elsewhere in the same region taking out the port of the agglomeration. Another possibility could be a relocation away from the original port to adjacent ports (Barke, 1986). The downstream developments of the European ports wherein new port developments were built more downstream along the estuaries away from the original city is a good illustration of this process.

Hayuth in a empirical study of US ports found out that concentration as he puts it is still not more than a theory. He has not been able to find real evidence for concentration among the studied ports. According to him there is an initial tendency towards concentration, but later in the development the opposite occurs. His main explanations are to be found in the range of difficulties in expansion of the existing concentrated load centres and in the fact that smaller ports, in fear of losing out completely to the larger ones, would be tempted to take desperate measures to please the shipping lines to call at their ports. In the beginning there was scarcity in terms of handling capacity, forcing the carriers towards the few ports available, but later the handling capacity of terminals increased dramatically, offering an oversupply of load centres, and thus dispersing the traffic over all ports (Hayuth, 1988). This is counter intuitive with the current trend of limiting the number of ports of call of the carriers. This is in order to reduce the voyage costs, and to maximise on economies of scale. However, Hayuth puts forward that this does not necessarily imply that all carriers would frequent the same ports of call. This is especially strengthened by carriers owning own terminals at certain ports. This can indeed be observed in the fact that MSC one of the largest shipping lines does not call at Rotterdam, but does call at Antwerp where it owns its own dedicated terminal.

In 1992 Kuby and Reid wrote an article about traffic concentration in U.S. Ports over the period from 1970 to 1988. In the article they see an opposite trend to what Hayuth has observed. They claim that the theory proposed by Slack by adding the extra phase to Taaffe, Morrill and Gould's model is supported by empirical backing. They, using the Gini coefficient as an index for concentration, have proven that the trend in general cargo in U.S. Ports is, contrary to what Hayuth shows, indeed converging towards more concentration. The reason for this concentration is technological changes in four different fields. They identify the increase in size of ships and trains, the higher degree of containerisation, automation of billing and easier tracing of the containers through computers as the four major drivers of change.

In an analysis of European seaports Notteboom checked for Hayuth's theory. He indeed found that also in Europe there was stagnation of concentration in the 1990's, however he found no evidence for the so called peripheral port challenge of Haytuh. Notteboom states that the only real alternative for the larger ports within the Hamburg – Le Havre range is Zeebrugge which is located further away from the hinterland. Furthermore, regarding the Mediterranean ports he claims that the shift towards medium sized ports has more to do with the fact that the location of these ports is more favourable in performing a hub function in the round the world routing of the carriers (Notteboom, 1997). He concludes by saying that the future of the European port system will not be entangled in striving to lure carriers, but will focus much more on the wish of the liners to offer door to door services to their customers and therefore might leave some container ports for others. This is more in line with the at the publication time much criticised triptych model (foreland-port-hinterland) proposed by Vigarié (Vigarié, 1979). Furthermore this implies that the connections to the hinterland are key in the success of a port in retaining an edge over the rivals.

In yet another study of U.S. ports McCalla, examining the eastern ports has found evidence for deconcentration from New York towards smaller more remote ports. In the trend of declining share of the eastern seaboard ports regarding world wide trade from 1975 onwards, the Canadian ports have according to McCalla been able to maintain the share within the range while the largest ports in the U.S. north-east notably New York have lost quite considerably to secondary ports. Containerisation, larger vessels, changes in hinterland routes of the different modalities and alliances in liner shipping have all contributed to the fact the range itself has lost a quite considerable part of its global share. The phenomenon of individual loss is according to him mostly the result of the (in)flexibility of the ports in question is the response to the afore mentioned global factors. Another factor that might have played a role is the growth in the southern part of the United States of America. The south saw both a increase in population as well as a sharp increase in manufacturing. This in addition to an expansion and modernisation of the terminal facilities and hinterland infrastructure have helped capturing cargo that previously was handled in the more northern ports (McCalla, 1999).

Rodrigue identifies the terminal as the main spill for improving the transport system. He comes up with a description of the space-time collapse caused by globalisation. This space-time collapse is the result of massive improvements in transportation and the extensive infrastructural investments. Therefore both time and space no longer really matter, as information is available every single moment, and the spatial dimension has all but disappeared through cheap, reliable and fast transport infrastructure. In his paper he examines the approaches of notably Comair and UPS in the United States of America, and he concludes that through synchronisation they have been able to capitalise on economies of scale. In his conclusion, Rodrigue writes that in terminals alone real time saving can occur, and therefore form the backbone of improvements. He also remarks that both studied companies have been able, through deregulation, to synchronise on different levels, thus augmenting the terminal efficiency. There is a danger of synchronising too much, as the level of synchronisation goes up, not only the efficiency goes up, but the instability increases as well. This might lead to a point wherein the the whole process turns up side down, with the efficiency going down again as the instability remains increasing (Rodrigue, 1999).

Finally from the perspective of the carriers, Wiegmans et al. have researched the most important aspects considered by the shipping lines to opt for a certain port and within a port for a certain terminal. They have looked into the decision making in the Hamburg – Le Havre port range. Their main findings are that regarding ports the alliance strategy has a great influence on where to call; next the emphasis is put on the hinterland connections , the port dues and handling costs, and the size of the hinterland served by the port. On a lower plan, but for some carriers of importance come green issues and feedering possibilities. Regarding the terminal choice within a port, the focus is mainly on the reliability, the speed, handling costs, and also hinterland connections. The authors conclude by stating that this decision making is not fixed for all cases, it is clear that deciding on these issues depends highly on what route and what trade is in question (Wiegmans et al., 2008).

Although from different angles, all afore named scholars have emphasised on the fact that hinterland connections and the terminals facilitating the modal split are essential for the position of the seaport both within the supply chain and network as for the competitive advantage vis à vis the main direct rivals. The focus now will be more on the hinterland accessibility.

3.2 Hinterland access

Notteboom and Rodrigue in another work have looked quite extensively into inland freight distribution. Shippers having more access to information are increasingly able to ascertain where the costs are incurred in the entire transport chain. This pressurises all the operations within the logistical cord. Since the largest part of the total costs are made in the so called last mile, in other words the last leg of the journey, inland transportation has become of eminent importance for the competition between the distribution chains. In this last leg there is still room for improvement and inland logistics have thus become the key focus of all players involved in the distribution chain. They have dug further into this regionalisation stage of port development. They state that the logistical integration is mainly responsible for this stage. Supply chains have evolved in such a way that this vertical integration was the more logical step to take for the parties within the chain. This has to do with a search for more control, the further profiting of economies of scale in the overall chain and the ambition to provide door to door services to the consignees. To be able to capitalise on this inland part of the haulage, the main access routes and inland terminals become vital elements. The aim is not only to enlarge the capacity but more importantly to alter the intermodal facilities in such way that the efficiency of the entire transport improves. With the enlargement of the hinterlands more inland terminals have been set up, and in Europe especially a more complex network of terminals now exists with not all terminals directly linked to the main seaport. The emergence of more inland terminals have helped to bring down the share of road transport to the advantage of rail and barge transport. Notteboom and Rodrigue recognise the difference between continuous hinterlands and discontinuous hinterlands. The last being the farther away from the seaport, but on one of the main axes and thus becoming part of the hinterland without being attached to the original port hinterland. A discontinuous hinterland within a hinterland of a rival port is referred to as island by the two authors (Notteboom and Rodrigue, 2004).

Important is to mention the main functions of those inland terminals. First and by far the most important function, in order to achieve economies of scale the number of transported containers should be such large enough. Therefore the terminals have been developed into locations where freight is bundled. In this function the terminal influences the degree of concentration. A terminal used by a rather small seaport can connect this seaport to large hinterlands, and thus cause deconcentration as was mentioned in the model proposed by Hayuth. But foremost the terminal enhances concentration by generating the critical mass needed for economies of scale, and in doing so they foster concentration in the larger ports with whom they are connected. As described by Rodrigue, there is a limit to this as the instability of the system increase with increased bundling (Rodrigue, 1999). Second, inland terminals function as pivots in the consolidation of freight. Consignees and freight forwarders use terminals to synchronise different batches in such way that cargoes needed simultaneously in production processes do also arrive together in time. Third, in a more recent development the terminals have been attracting companies providing value added services. In doing so the terminals have become part of logistical zones accommodating a wide range of activities from repair centres to repackaging and labelling facilities (Notteboom and Rodrigue, 2004). The authors show the trend of concentrations of logistical companies away from the seaports in north-western Europe. According to them, it is a result of a market driven process rather than an imposed relocations of activities. However they do see alterations in the spatial approach to governance of the seaport since regionalisation can be a key element in competition of seaports.

In an analysis on the role of the port authority Notteboom and Rodrigue point out at the gradual change from public entity to a more privatised or corporatised form of governance in which the landlord function is the only function left within the port itself (Jacob and Hall, 2007). However they still see major roles to play in the regionalisation phase of development. First, efficiency of modal split should be the ultimate aim. This task comprises of involvement in large infrastructural projects to reassure good hinterland connections in order to lift higher the level of competition among the modalities. Second, strong ties or even corporate linkages with inland nodes and terminals can ameliorate the competitive position of both seaport and terminal. This enlargement of the spatial dimension of the port can be achieved by for instance investments in inland terminal facilities, strategic alliances or joint ventures. The goal is to strengthen the whole chain in order for all parties to profit from it (Notteboom and Rodrigue, 2004).

In a more governance oriented article De Langen and Chouly have analysed the hinterland access regimes (or HAR's) of seaports. They too view that global developments are imposing a new competitive framework for seaports especially in container throughput. According to them the quality of hinterland services become the focus of the ports, but it is not to the port alone to achieve this for many actors are active in the hinterland. Therefore they conclude that the improvement is an action on an inter-organisational level or a collective action problem (or CAP) as they put it. They define the hinterland access regimes as: “the set of collaborative initiatives, taken by the relevant actors in the port cluster with the aim to improve the quality of the hinterland access”[6]. They produce five variables that affect the HAR. The existence of institutions or organisations that accommodate collective action; the role of public entities in a regime; the fact that partners can have a say in changes if these are not to their satisfaction; a sense of community, that helps cooperation; and finally, the presence of one or more leading firms that can can take the initiative. The authors provide with an empirical study of three port regions, Rotterdam, the port cluster around New Orleans on the Mississippi and Durban. They identify Rotterdam as the location of most developed HAR, and the reason for this is based on the fact that already for a long time, Rotterdam has well developed cooperation within the port community (De Langen and Chouly, 2004).

Panayides has examined the organisation of intermodal transportation from a transaction cost perspective. Here too the approach is more from a governance side than from an operations point of view. Transaction costs are mainly the costs involved in gathering information and in monitoring the negotiated deal. These costs are incurred when firms or organisations interact both in the initial stage of contracting and in the stage of enforcement of the contract. In the transaction cost concept vertical integration might lead to lowering of the transaction costs since a larger part of the chain is under own scrutiny. Panayides claims that the organisational form of intermodal transportation is a result of three main cost drivers: “the costs of production, transaction costs, and the strategic costs and benefits associated with the different governance structures”[7]. His research shows that there is evidence for transaction costs involved in the way intermodal transportation is structured, and that vertical integration among the parties involved can lead to lowering of these costs. This can however not be done

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[6] De Langen and Chouly, 2004 p 363

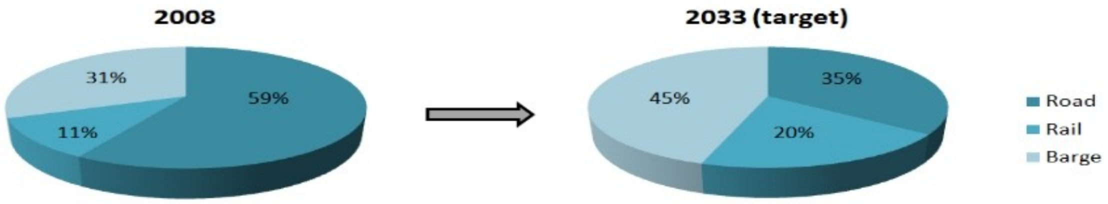
[7] Panayides, 2002 p 405

without taking into account the other mentioned cost drivers, if one wants to optimise the organisational framework. There is according to the author also a downside to vertical integration, concluding from his application of the theory on the carrier business, as it raises entry barriers for newcomers and the fact that the carriers would have overwhelming power over the other parties considering the sheer size of the companies compared to the other players. But he still sees possibilities for competitive advantage in intermodal transportation (Panayides, 2002).

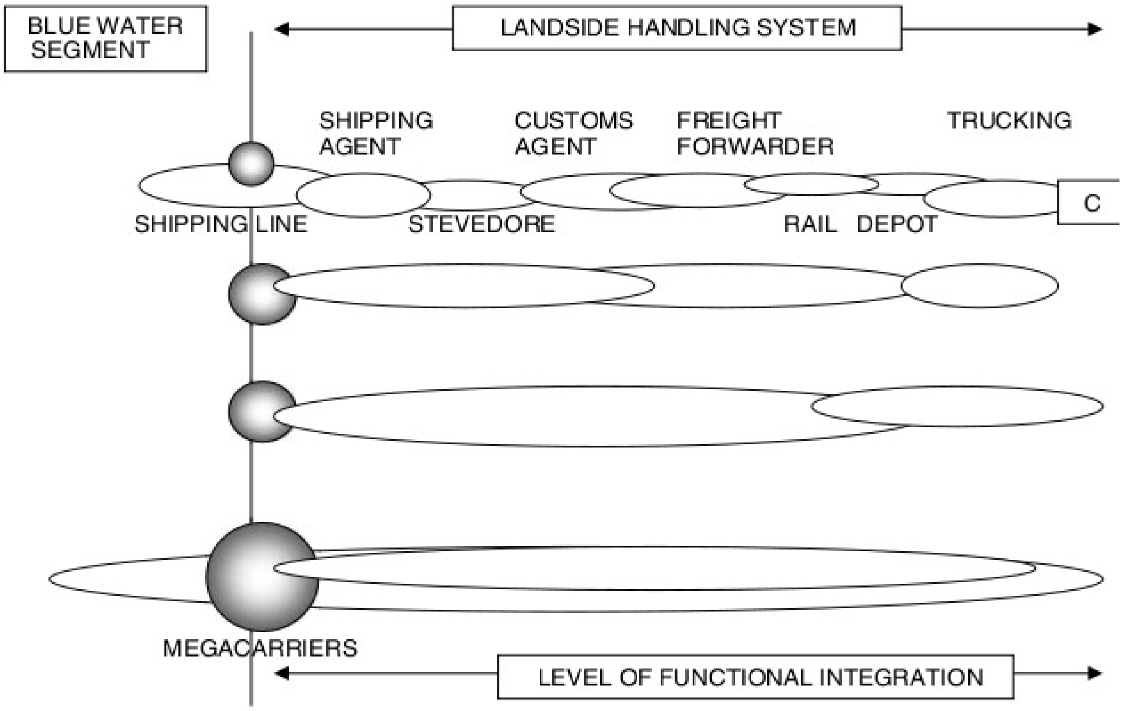
De Langen and Van Der Horst analyse the hinterland transportation chain from an inter-organisational point of view. They come up with four major reasons for coordination problems in the distribution chain. First, there is no equilibrium in the advantages and costs of coordination. For the entire chain this might be the case but typically for a party within the chain this is not the case. Second, there is reluctance to invest in the coordination of the hinterland. Third, there is the fact that parties involved would out of strategic behaviour, prefer to stay aside when asked to contribute, but may as well profit from the benefits offered. Fourth, the parties in hinterland transportation are often risk-averse concerning new projects. Next to these problems that might occur, the authors present four types of solutions to these problems. First, there is the application of an incentive scheme, this solution is derived the property rights theory. Second, partnerships could be introduced. Third, vertical integration can take place, changing the scope of the firms. These last two solutions come from the transaction cost theory also proposed by Panayides. And fourth, collective actions could be created, and this type of solving the problem has its roots in both the collective action theory and the property rights theory. Specifically applied to the case of the port of Rotterdam, the authors come up with a list of problems occurring in the port and they propose certain paths based on their framework of solution to solve the problems encountered (De Langen and Van Der Horst, 2008). This thesis is looking into one of these problems namely the long stay of barges at the terminals in the seaport and the resulting inefficiencies in hinterland transportation of containers by barge.

Concluding from the literature review, it is clear that the dynamics of contemporary container handling involve a bit more than berthing space and a crane. The challenges faced by the ports are numerous, but they are increasingly faced to deal with issues that go beyond the scope of the traditional port model. Hinterland transportation seems to become the main target points in competition as in the inland access consists of 18% of the logistical costs (Notteboom and Rodrigue, 2004). Major cost reduction on the inland leg could be made since the operations are run far from efficient.

Because of vertical integration in the logistic chains, the position of ports world wide become more and more locked within large supply chains. It is therefore essential for ports to assure reliable and efficient connections to the hinterlands in order no to lose out to competitors. Port authorities can take up the leading role within the port communities to present efficient solutions wherein all parties can gain.



Current and targeted modal split for the port of Rotterdam. Source percentages Port of Rotterdam.



Schematic representation of vertical integration in hinterland transport by carriers. Source Robinson, 2002.

Section 4

Modelling

4.1 Introduction

The last decade or so port congestion has become an increasing issue for deep-sea terminals in the major ports, especially in the United States of America and in Europe. As congestion has become a more structural phenomenon, it causes suffering for almost all parties in the supply chain. The past and current year form an exception to this rule because of the extremely sharp economic crisis the world is going through right now. However it is the expectation that ultimately trade will pick up again and the growth will show a similar rate as seen up to the crisis. The shipping lines can because of delays miss the time windows in later ports of call and be charged for it, or might even be forced to alter the sailing schedules, probably demanding more bunker. Terminals can be hindered in the yard planning because of late arrivals of ships. Initial delays of ocean vessels also affect the hinterland connections as they depend on when the vessels arrive and because of lack of contractual relationship with the terminal will end up being served latest. This pressurises the reliability of the entire supply chain, with financial consequences for shippers that cannot obtain their goods on time.

The standard solution is to raise capacity by acquiring better handling equipment and additional berthing space. This does partially solve the difficulties, but does not offer the solution for the hinterland connections. For the hinterland connections there is also another structural congestion as well next to this induced congestion from the sea terminals. The volumes and dynamics have changed a lot over time but the sailing practices and routing schedules have not changed accordingly. The widespread use of containers has enlarged the hinterlands considerably (De Langen and Chouly, 2004). This too has contributed to a further congestion of the hinterland connections. This is just the field in which the ports have to compete, and therefore the hinterland connection should be cheap, reliable and fast.

Ports that have been confronted with these problems have tried to alter the whole concept of the port. A popular strategy especially among politicians is to shift the port entrance towards a more inland location. This location might function as a pick up point in the hinterland connection. Both traffic bound for the port as well as the traffic bound for the hinterland are collected at a central point away from the port. The idea has been put into practice in some U.S. ports, and these inland satellite terminals might also fulfil other functions than only a pick up point (Slack, 1999). Custom clearing in the U.S. takes quite a while and with the ambition to scan and screen 100% of the containers, a remote location away from the congested port would form the ideal solution. Although I am not really fond of the 100% scanning and screening scheme in terms of usefulness and practicability, to introduce such a scheme is a political debate. However to me it sounds a little awkward that the so called dangerous goods i.e. dirty bombs from which the U.S. has to be protect are first driven from the port through densely populated cities to the satellite terminal first before being checked. From a pure cost driven perspective I think the satellite terminal concept where all containers are first moved away from the port to be transported further on would only be achievable if road was the only mode of transport. Both rail and barge transport would require an additional handling of the container making satellite terminal operations both expensive and time consuming.

Other popular solutions can be found in using other types of barges. Push barges are barge combination with an engine mounted on a vessel that pushes one or several barges or pontoons. These barges or pontoons can easily be detached and mounted back again. Filling the pontoons while the ship itself is not at the terminal facility can solve a great deal of the congestion at the terminal. The ship simply passes by, detaches its pontoons destined for that terminal and picks up the already filled pontoons for another leg of the sailing. This way of sailing increases dramatically the productive time the vessel is in use. However for the specific problem in the port of Rotterdam it only brings a solution to a small part of the problem. The aforementioned method only works when full loads are destined for the terminal. A full pontoon is detached and another full one is mounted. One of the main drivers of the congestion problem is the fact that there are so many small size calls to make. With calls of a dozen or so containers using an entire pontoon would result in very low fill rates of the push barges and thus although the productive time is much higher it still remains to be seen if the combination is at all economically viable.

As mentioned before, Rotterdam is the largest container port in Europe. The increase in TEU's over the period 1995 to 2005 was around 95%, and this volume is expected to grow with another 70% to around 16 million TEU's in 2020[8]. Only the most western part of the port, the Maasvlakte is able to receive the largest container vessels in the fleet. The by some expected 18000 TEU vessels and more that are currently on the drawing boards can even be handled without changes or further dredging. However if theses huge vessels would come into service, the performance of the terminals and the hinterland connections will have to cope with those larger flows, and will certainly come under even more pressure than currently. With the expansion of the port, the second Maasvlakte, scheduled to be finished by 2013, the overwhelming majority of the containers will be handled on the most western tip of the port. Currently already 65% of all container handling takes place at the Maasvlakte.

4.2 Barging problem in Rotterdam

The port area is largely dependent on one single motorway the A15 for all road haulage. This road although equipped with three lanes in both directions for the largest part around the city, is not able to cope with both lorries transporting containers to the hinterland and commuters to and from Rotterdam. Social pressure in western Europe has moved the awareness of the people towards more environmentally sustainable solutions. Lorry traffic is by most seen as polluting . The other two modes of inland transportation, rail and barge are regarded as more environmental friendly as the emissions of noxious gasses per tonne kilometre are far lower for the latter two modes than for trucking. Some people, especially from the road transport side do claim that the current engines that are classified in the Euro 5 category and higher are less pollutant than most barges. Lorry manufacturers have over the last years been able to cut back considerably on emissions while such steps forward have not taken place by the engine producers of the barges. Besides barges are in service for quite some years implying that a great share of the barge fleet does not meet the current emission standards. I will not continue on debating this issue further, because anyway the political accepted view is that a barge is less polluting, and therefore barging is preferred over trucking. Besides, from a pure efficiency point of view barges are to be preferred because they do not clog up the roads.

Rotterdam currently copes with congestion both in the port as well as outside. Far away from the eye of the general public, on the waters of the port there is quite some congestion especially for barges waiting for their turn at the various terminals. On rail a similar situation

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[8] Figures from the municipality of Rotterdam and the Rotterdam port authority

occurs as the liberalisation of the rail network has produced around 12 different rail companies, currently all using own storage facilities for wagons. The trains have to call at all different the terminals to gather their freight and thus causing delays as all companies have to await their turn. Trains often spend more than 24 hours before being able to leave the ports because of all the waiting time.

On the barge side situations are often worse. Some barges may take up to three days before being able to sail away from the port. There are several causes for this problem.

First, the barge operators do not have a contractual relationship with the terminals where they have to collect or discharge their containers. This means that both parties do not feel any obligation towards each other nor have they the ability to fine or penalise the other party for either missing the appointment time window or for mediocre service.

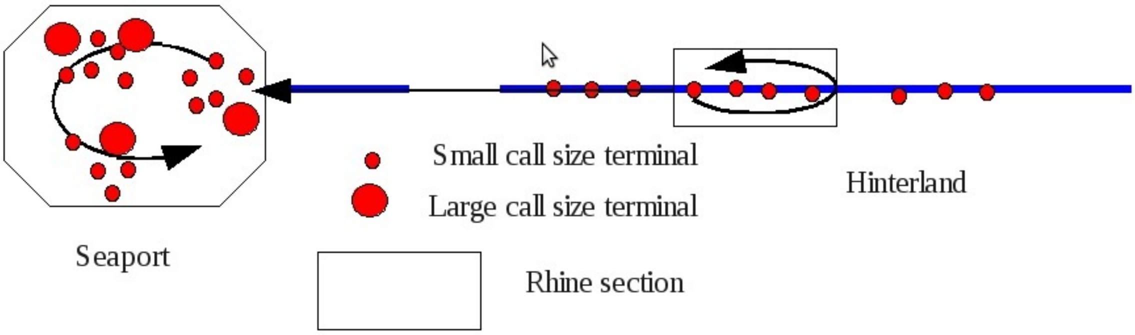
Second, because of the historical setting barging on the Rhine is organised in a certain way. As explained earlier the Rhine is parted in three different regions, the upper Rhine, the middle Rhine and the lower Rhine. All three regions have appeared in a different period in time. A path dependent development has taken place in the transport over the Rhine. To sail with barges with a higher fill rate the operator in the regions have organised themselves into alliances. The barges collect their cargo at different terminals within the region, typically they call at three to five terminals. At those terminals they collect containers bound for Rotterdam for themselves and some for an alliance member to fill the vessel. The favour is returned by other alliance members on other journeys. In the port of Rotterdam however numerous terminals have to be called at. This number usually lies between eight and thirteen terminals. The simple fact that the barges have to call at so many terminals already causes congestion in the port. On top of that, most calls in the seaport are fairly small in size through which the waiting time compared to the actual berthing time in disproportionally large. This has to do with the fact that sailing schedules from the Rhine regions have hardly changed while the amount of containers has grown considerably

Third, the trend in the modal split of the hinterland transportation is shifting more and more towards barging. This means that even more pressure will be put on this mode. The reasons for the shift come from two sides. In the ambition to opt for more environmental friendly haulage, politicians force the new terminals on the second Maasvlakte to barge a large share of their containers. Carriers as well have contributed to this trend as they try to differentiate their services by offering a “greener” way of transport. Next, the competitive position of barging has gained over road transport. This is because roads get more congested and the fact that the volumes are such that economies of scale are applicable also for lower Rhine destinations or origins.

Fourth, the global trend in trade although currently going down is still moving towards higher volumes of containers. This means that even with equal share along the modal split, a sharp increase of barging will take place.

As discussed earlier, the congestion and the consequent delays are costly and harmful to all parties involved in the transport chain, and can even deteriorate the competitive position of Rotterdam compared to its main rivals Antwerp and Hamburg.

I therefore look to ameliorate the barging situation in the port of Rotterdam. In the following section I will come up with various options of how to improve the calling patterns in such way that the number of calls in the port can be reduced.

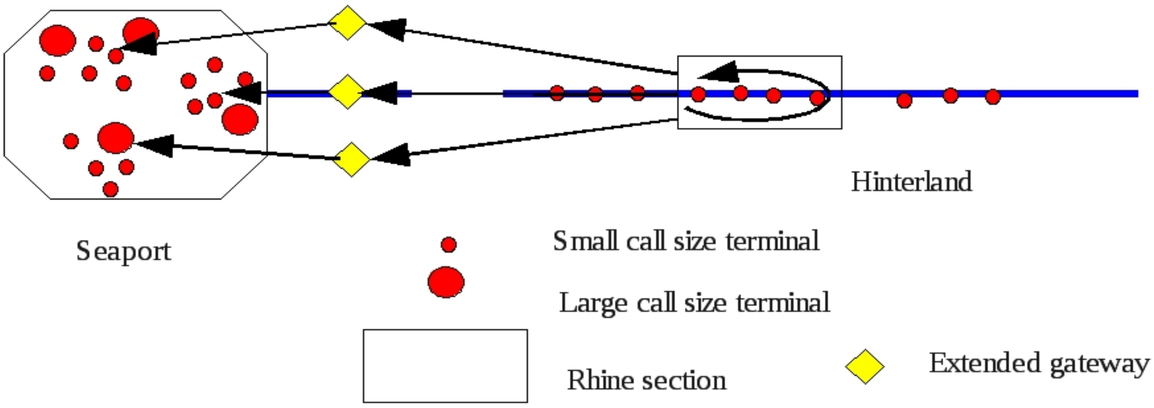


Current sailing pattern on the river and in the port

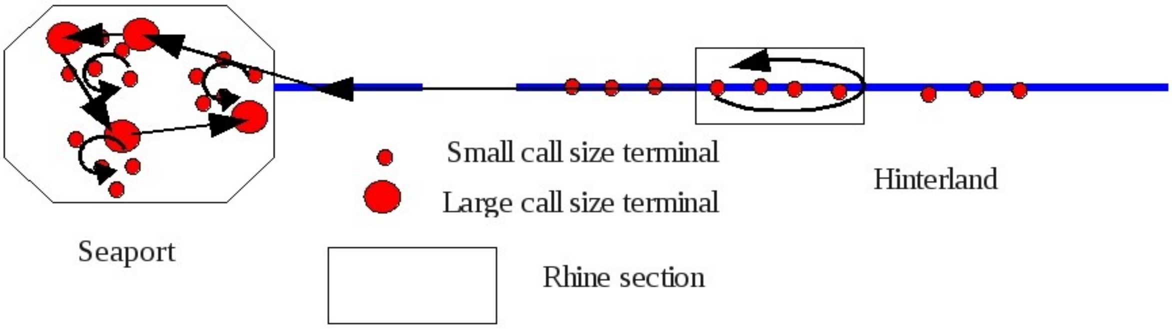
4.3 Proposed models

4.3.1 Extended gateway

Discussed already in the literature review, the extended gateway could provide a solution to the call problem. In this option one or several inland terminals have to be erected along the Rhine close to the port. These satellite terminals will become the pivotal points in the modal split. First the containers are transferred to the extended gateway terminals, and from there they are shipped onwards. If several terminals are used an early consolidation can take place from the seaport terminals. One could think for inland bound traffic that the consolidation can take place along the destination regions along the Rhine. In this case for example three different terminals could be used one for each inland destination section. Ideally it would be preferred to have a similar consolidation for seaport bound traffic. So with the same three terminals this would mean that one will serve the Eem/Waalhaven region, one will serve the Botlek region and one will serve the Maasvlakte. From extended gateway terminals, the containers will be shuttled to the seaport terminals of the respective regions. This will mean a dramatic reduction in calls for the barge operators, that would only have to sail from the hinterland to a maximum of three terminals for the discharge and only one terminal to load the inland bound containers. The advantage of the extended gateway concept is that also other modes of transport can make use of the terminals. Since rail and road traffic also encounter congestion in and around the port, these traffic flows can be spread by also connecting the extended gateway terminals to the road and rail infrastructure. Another advantage is that also custom functions can be performed away from the port, however I have already pointed out to whether this is really advantageous for security reasons. A major disadvantage is that all containers will have to be handled twice in the port, once in the extended gateway, and once in the seaport terminal of destination. This double handling can be costly and therefore other solutions should be considered with less double handling. Besides new terminals and infrastructure have to be built especially for the purpose, and those costs have to be recovered as well.



Sailing pattern with extended gateways



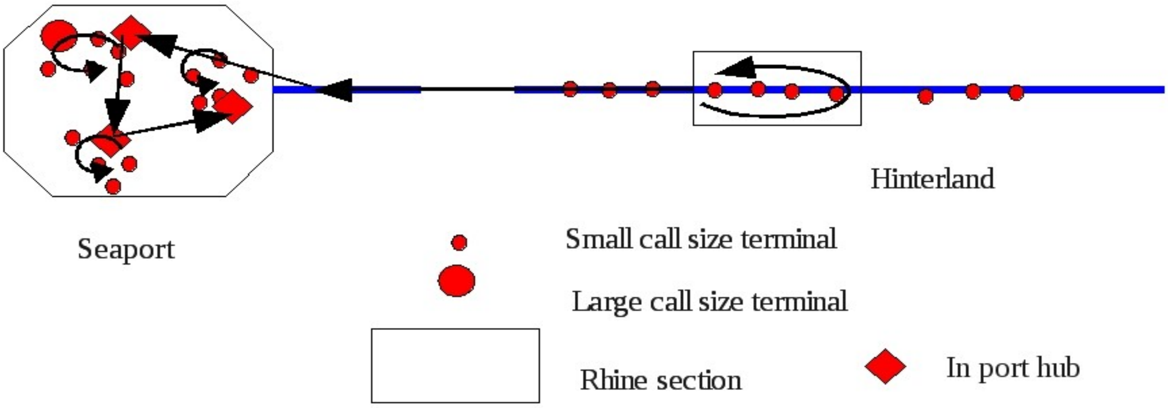
Sailing pattern with dropping off of small calls at larger terminals

4.3.2 Dropping off of small call sizes

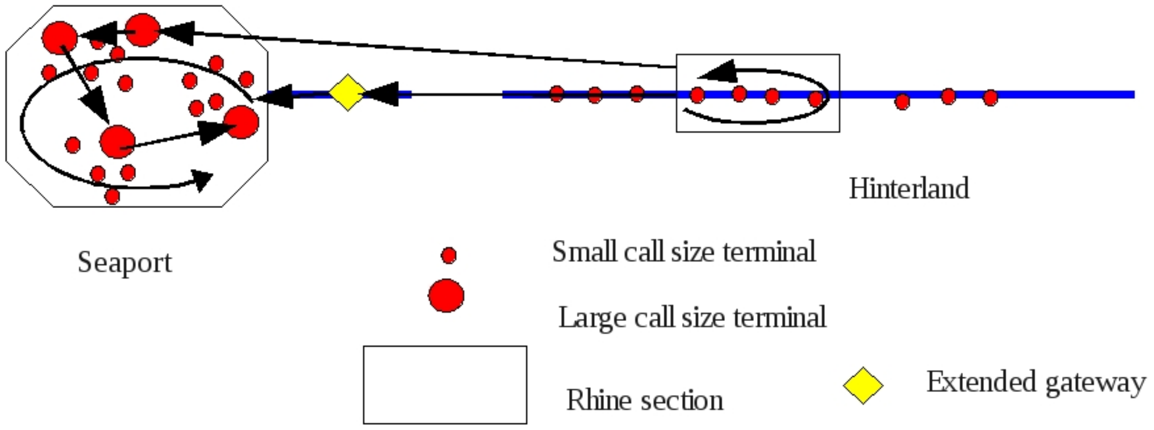
According to Konings 50% of all calls in the port of Rotterdam involve less than six boxes (Konings, 2007). An option could be to drop off and pick up those small call sizes at an other terminal. This would cut down the number of calls of the barges with around 50% although extra shuttles have to run between the terminals offsetting this number a bit. For inland bound containers, the small calls could be gathered at the original terminals and then shuttled to larger terminals where the call sizes are larger. From there the barges can pick up their load. For containers heading for Rotterdam the same can be done, by dropping off the containers of the small sizes at terminals where the barge stops anyway for a larger call. At those terminals they can be bundled per destination and then shuttled for the final leg to the ultimate destination. If the call size is really small and it would take a long time before having enough containers to shuttle, on could think of trucking the container from one terminal to another. In this case only a limited number of containers are double handled, reducing the extra costs considerably. However it does require extra space, although not to a great extend, on the yard at the terminals since the containers have to wait for further transport. The barges still have to call at quite some terminals in the port, so possibly the congestion can return with increasing trade and larger container volumes. But this can be countered by raising the number of boxes allowed to be discharged and loaded. To enforce such regulation, the port authority can simply forbid call sizes lower than a certain amount, but one can also think of a scheme in which terminals can give last priority to the barges that come for small calls, this could stimulate the barges either to come at quiet hours for small calls or to agree on participating. Another possibility is to charge an extra amount to the barge operators for small calls.

4.3.3 In port hubs

Another way of cutting down the call is to create three hubs in the port itself at the three main locations where the terminals are located. A newly built terminal is not needed since space on one of the existing terminals can be used for this purpose. The best solution would be to use the terminals where the largest amounts of containers are handled. In this option the barges only call at the three main in port hubs to load and discharge the freight. The containers are then shuttled from and to the other seaport terminals. This can be seen as a combination of the two aforementioned options. Here less calls are made by the barges than the dropping off of the small calls option, the downside is that more containers will undergo double handling raising the costs somehow. The containers that are not double handled are the containers originating from or destined to this large terminal functioning as hub. Another disadvantage is that in this case quite some space is needed for the temporary storage of the containers since the numbers are greater than in the previous option.



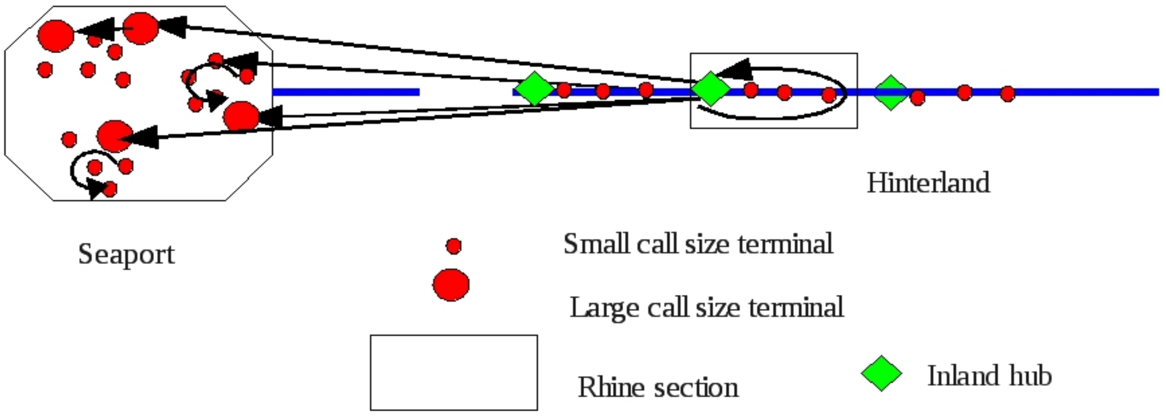
Sailing pattern with in port hub



Sailing pattern with extended gateway usage for small calls

4.3.4 Use of extended gateway for small sizes

Another combination could be to actually use an extended gateway terminal, but solely destine it for small call sizes. In this case only one extended gateway terminal would suffice because of the lower number of containers. The inland terminal planned in Albasserdam, the so called transferium would suit for this purpose. In this scheme the small calls have to be performed at the transferium terminal and the barges proceed to the rest of the terminals. From and to the transferium the containers are shuttled to the other terminals. Advantage of this option is that the double handling is limited to the small calls and that the transferring of the containers takes place at a neutral location, so that it does not require use of space on other terminals. And here again also other modes of transport can make use of the facility. The downside is that the transferium could easily get congested since still a lot of call have to be made there, but the advantage for the barges is that this waiting will only be confined to one location.



Sailing pattern with use of inland hubs

4.3.5 Major inland hubs

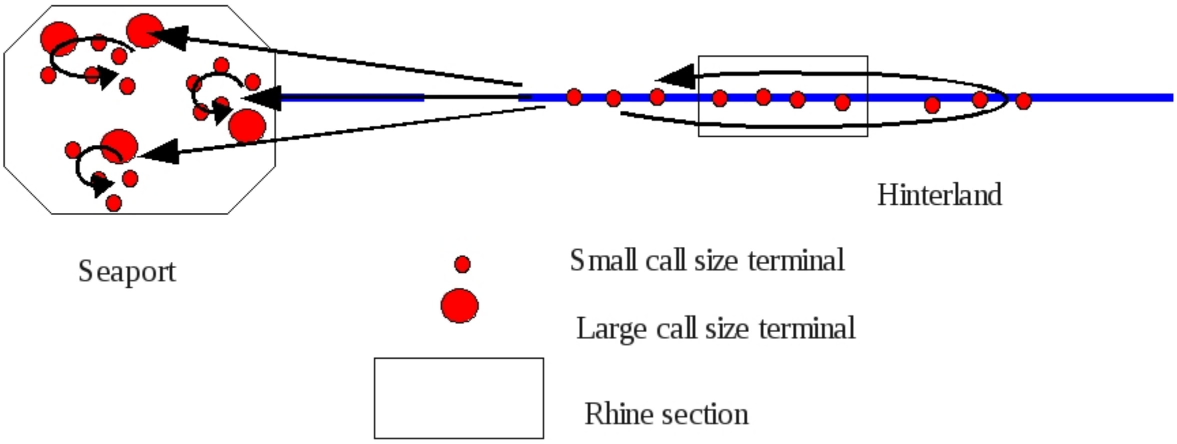
Another way of looking at the challenge is to perform the distribution much further on the river. One could think of one major inland hub on the three Rhine sections. The inland bound containers would be shuttled from the seaport terminals all the way to the hubs on the respective sections of the Rhine and from there they would be transferred to the desired destinations. For Rotterdam bound containers, the boxes would be gathered at the hub and then shuttled to the final terminal destination in the seaport. For smaller terminals in Rotterdam one could think of a shuttle calling at a number of terminals to ensure a regular service. Here again the major disadvantage is the fact that all containers are double handled if newly erected terminals would be used. If existing facilities would be used, they would need expansion which is hard to realise in most locations since they often are situated in cities. This type of hubbing has an advantage over using the Rotterdam terminals as hubs since the Rotterdam terminals are much busier since also short sea and deep sea vessels call there. The best benefit is however the considerable decrease of barge movements in the port, and even on the Rhine since the largest leg of the journey can in this case be done by larger push barges, and the further feedering by the smaller counterparts. But still all double handled containers cause extra costs.

4.3.6 Separation of destinations

Currently all terminals in Rotterdam are seen as one single destination for barges from the German hinterland. If the three regions with container terminals could become separate destinations, the number of calls and movements in the port could be reduced by a lot. In order to keep the same sailing frequency and fill rate, the barges will have to call more in the hinterland. Because of the simple fact that calls in hinterland terminals require less time than calls at terminals in the seaport, this still would imply a considerable time gain. This option requires no extra investments in terminal capacity or double handling of containers and therefore can be executed at the same costs as current operations. Furthermore the implementation does not need a lot of changes in organisational structure either, so it could be implemented within limited amount of time. In a very extreme version of this scheme one could even think of making all Rotterdam terminals separate destinations. In that case there would be no sailing at all between or among the terminals in Rotterdam by the barges. The only two in port services would be the repositioning of empty containers and the containers that are destined for transshipment from another terminal. This can only be done if the container flows to all terminals would be large enough to maintain a regular service; which is currently not the case for the smaller terminals.

Another option would be to take away the separation on the Rhine of the three sections. Currently a barge calls on average between three and five times within the section. If the separation of the sections would be abolished, more hinterland calls could be made, since operations are not any more confined to the home section, and therefore the consolidation of the freight would be as such that the number of calls in the port of Rotterdam can be limited with same sailing frequency. Since calls in the hinterland are less time consuming as in the seaport, hereto it is obvious that there is a gain. Also in this case the implementation could be done without large investments, and pretty fast. On the Yangtze river it does happen, although not widespread that operators from one section of the river pick up loads in other sections as well (Notteboom, 2007a).

Again another option within the same range as the previous two, could be to join forces more than currently is the case. The Fahrgemeinschaften as they were introduced in the third development phase in Rhine barging could be reinstated. They have not completely vanished, but currently the few alliances that are left are more cooperating in the field of planning of services. Originally the alliances were formed because the fill rate of the barges was so low that no profit could be earned from sailing. Therefore the barge operators decided to join hands and plan trips together. The alliances lost their importance when the flows of containers increased and were not needed any more to gain from operations. The current problem does not lie any more in filling the barges, but in the number of calls. If barge operators would again be willing to transport each others' containers, the consolidation could thus be made that the number of calls can be reduced. Now it often happens that several barges originating from the same hinterland sections sail to exactly the same terminals in the port of Rotterdam. This could be avoided if they would be transporting each others' load. This type of slot sharing is common in the deep sea sailings, but has not yet been implemented in barging. In practice this would mean that certain barges will only call at certain terminal, and that the rest of the destination terminals within the port are served by other barge operators.



Sailing pattern with separate destinations in the port and out of section pick ups in the hinterland

Section 5

Discussion and model

5.1 Discussion

In the previous section I have discussed a few different options to reduce the number of calls vowing to solve the congestion in the port of Rotterdam. All solutions might work in theory but it does not necessarily mean that it can be implemented, let alone that it would work properly in practice. Also the difficulty of any implementation would lie in the equilibrium between the various targets. An ideal solution for hinterland transportation would meet at least these three requirements: it should be cost effective, it should be reliable and it should be fast. Double handling of containers although it does require extra time, in the configurations as I have proposed could provide a faster service but at a premium.

Konings has looked into a number of options of double handling in splitting the operations in three different regions very much like I have proposed. He calculated the net benefit based on the benefit of additional volumes, the marginal costs of chartering extra capacity and the feedering costs. What he calls feerdering costs, is equal to the costs made for shuttling the containers from one terminal to another. Because of lack of comparative data, he based these shuttling costs on the price paid for shuttling empty containers to depots within the port. His conclusion was that against the prices on the market in 2007 both the concept of a transferium where small batches of containers could be dropped off or collected, and the model with a hub function of terminals within each of the three port regions could be above the break even point, but only for the trade to the middle Rhine section and not for the other two sections (Konings, 2007). On top of that he did not take into account the extra costs incurred for building the transferium and the compensation for loss of space on the yard of the terminals used, or the fee that has to be paid for it.

I would therefore opt to look more into the options that do not require substantial extra costs. I have focussed on changing the calling patterns in a way wherein the number of terminals that are called at in the port is minimised. For that purpose I have constructed a simple theoretical calculation model in which I can compare different scenarios. The model is set up with six terminals in each hinterland section and six terminals in the port but can easily be expanded to mimic the actuality a bit better. In addition three types of barges sail around with all different capacity, and difference in sailing speed whereby the smaller vessels are the fastest and the larger vessels the slowest. The model is constructed as such that handling speed, sailing speed, and numbers of containers per origin and destination can be varied. This model can be expanded to more terminals to approach the true situation better if wanted, but so far I have concentrated on theoretical issues. I also have added a kind of cost component wherein handling costs and sailing costs can be calculated. Here sailing by larger barge would mean a lower sailing cost per TEU.

I have so far looked at the origins in the hinterland and destinations in the port, but this can obviously be turned around with ease. In the model I have compared two extremes in the hinterland transport. One of them being sailings from one origin terminal to call at all seaport terminals. The other one is the other way around, to have sailings only calling at one seaport terminal and at all origin terminals. If no containers have to be loaded or unloaded no time has been calculated. If more than one barge is required for the transport, I have summed the times spent by the barges. The goal of this exercise was to simulate one period of sailing and to see whether the proposed theoretical solution i.e. call at more terminals in the hinterland and at less terminals in the port, would really be more beneficial. The outcomes indeed back the theory. Both in terms of costs and in time the option with several calls in the hinterland sailing to one single destination in the port seems to come out on top with the same amount of barges, however with the parameters I have used the difference in time was not more than 5%. However I have not put into the model the chance of delays. I have solely used one hour of waiting time on average for calls in the hinterland and three hours of waiting time for calls at the seaport in addition to the actual handling time. Delays are difficult to put into the model but it is clear that if delays might occur, and that happens in most cases that the difference will only increase in favour of the proposed routing. This is because delays are more likely to occur in the port than in the hinterlands, with one delay causing many more delays in time for barge and terminal, and thus for other barges as well. Delays in the hinterland can be countered by faster sailing.

This at least proves that improvement can be achieved in theory. However, barge operators want to sail on fixed schedules. A weekly service for instance for lower Rhine origins is normal. If time is won in such way that a round service can be completed in six day, it is still to be seen whether operators would be willing to have a faster service. The point in this is that the companies that actually sail the barges are often hired for a quite lengthy period and to the barge operator it can be seen as a fixed cost. However the container volumes are expected to go up in the future, and with that in mind it could well be that the time saved in waiting can be spent in handling the extra containers. This means that for the same service frequency as is currently maintained, the operators could sail with larger barges, transporting more containers and thus earning more money. With the time saved in the port they could also make the sailing loop wider, and in doing so call at a few more terminals in the hinterland, and that too would help them to transport more containers.

Another point is the fact that more inland terminals are called at in one of the proposed solutions. The calling patterns could become a complicated issue. The sailings are now maintained in such ways that the call at the hinterland terminals occur at the opening hours of the terminals. It could well be that one or two extra calls will imply that some loading and discharging has to take place in the evening hours, when the terminals are normally closed. This sets pressure to come up with very detailed routings and call patterns in order to avoid nightly calls, or will induce extra costs for night work, if terminal operators are willing to be open at these times anyway.

5.2 Calculation model

To examine the effect of bundling freight I have constructed yet another calculation model. This calculation model aims at minimising the total time taken by the route. This includes the sailing time, the waiting time at the terminals and the time spent discharging and loading.

In theory there are four main different types of decisions made on the tactical level of an inland transportation firm. First, there is the selection of services. In this case the decision is based on the specific assets of the routing. The sail frequency is an example of this category. Second, one can identify the specific route chosen for a certain service. This can be named distribution selection and type of services or terminals called at are examples of this selection. Third, there is a policy decision regarding terminals. This can include the actual performance at the terminals and allocation of handling among the set of terminals. And fourth, there is the issue of empty containers. Due to trade imbalances there will always be empty containers that have to be repositioned to locations where they are needed. Although this involves complex logistics, from a pure terminal or barge operator point of view the handling of an empty container is no different than that of a full one except for the fact that it is counted as an unproductive move.

There are two basic types of models used in transportation, simulation models and optimisation models. The simulation models are ideal to compute scenarios and oversee what is actually happening in each different location of the transport chain. The optimisation models are used to strive for the most efficient solution for the entire network or chain. This last type of modelling is chosen for the selection of a more efficient strategy in call patterns in the main objective of the exercise.

Most models are based on cost minimisation, I however, because the costs involved are not transparent and are fluctuating in time have opted for an efficiency optimisation in time. Delays and congestion are the main problems in the port of Rotterdam, and solving them will not necessarily mean the cheapest solution, however I think that with an optimal solution regarding time could also involve less costs as the saved time can be used for transportation of more containers, or sailing at slower speed and thus decreasing the fuel costs.

The model I have constructed is based on the models proposed by Crainic (Crainic, 2000). It is a theoretical model in which the sailings can be optimised in such way that the total time taken by the barges is minimised. The time span is one period, and the assumption is that all routes including handling and waiting can be performed within that period.

For reasons of simplification I have assumed a stream of containers bound from the hinterland towards the port. For round-trips trade imbalances should be taken into account. Because the model has to reflect the sailings on the Rhine, the graph can be assumed one dimensional with calling patterns only in one order, from more upstream to downstream.

The parameters and decision variables of the model are:
$G=(N,A)$ = graph G with nodes N and arcs A

A = set of arcs

$(i;j)$ = link between terminal locations i and j with i more upstream than j

o = origin terminal

d = destination terminal

N = set of nodes (terminals)

N^u = set of inland terminals

N^r = set of port terminals

$N^u \subset N$

$N^r \subset N$

$N^u + N^r = N$

u = inland terminal with u_x more upstream than u_{x+1}

r = port terminal with r_x more upstream than r_{x+1}

$u \in N^u$

$r \in N^r$

$o \in N^u$

$r \in N^r$

$p = (o;d)$ = product with origin o and destination d

P = set of products (origin – destination pairs)

$p \in P$

P^o = set of products with origin o

P^d = set of products with destination d

$P^o \subset P$

$P^d \subset P$

l = path in network

L = set of paths in network

$l_{(i;j)}^p$ = path $(i;j)$ for product p

L^p = set of paths for product p

$l \in L$

$L^p \subset L$

$y_{(i;j)}$ = 1 if link $(i;j)$ is open else = 0

$y_{(i;j)}^{lp}$ = 1 if link $(i;j)$ belongs to path $l \in L^p$ for product p else = 0

Y = set of links y

Y^{lp} = set of links on path $l \in L^p$ for product p

$y_{(i;j)} \in Y$

$y_{(i;j)}^{lp} \in Y^{lp}$

$Y^{lp} \subset Y$

w^p = demand for product p

f_l^p = flow of commodity p on path l

b^l = number of barges on path l

q^l = maximum fill rate of barges on path l

c^l = maximum capacity of barges on path l

n_u^{lp} = 1 if inland terminal u belongs to path $l \in L^p$ for product p else = 0

n_r^{lp} = 1 if port terminal r belongs to path $l \in L^p$ for product p else = 0

k_u = waiting time in inland terminal u

k_r = waiting time in port terminal r

z_o = handling rate (crane productivity) in origin terminal o

z_d = handling rate (crane productivity) in destination terminal d

$s_{(i;j)}$ = sailing speed on link $(i;j)$

$h_{(i;j)}$ = distance between terminal locations i and j

this leads to the following objective function:

$$\text{Minimise} \sum_{p \in P} \sum_{l \in L^p} b^l \cdot \left(\sum_{u \in N^u} n_u^{lp} \cdot k_u + \sum_{r \in N^r} n_r^{lp} \cdot k_r + \frac{w^{(o;d)}}{z_o} + \frac{w^{(o;d)}}{z_d} + \sum_{y^{lp} \in Y^{lp}} \frac{h_{(i;j)} \cdot y_{(i;j)}^{lp}}{s_{(i;j)}} \right) \qquad (1)$$

subject to

$$\sum_{u=0}^{u} \sum_{p \in P^o} \sum_{l \in L^p} b^l \cdot q^l \cdot c^l \cdot n_u^{lp} \geq \sum_{u=0}^{u} \sum_{p \in P^o} w^p \, \forall \, o \in N^u \qquad (2)$$

$$\sum_{u=0}^{u} \sum_{p \in P^o} \sum_{l \in L^p} b^l \cdot q^l \cdot c^l \cdot n_r^{lp} \geq \sum_{u=0}^{u} \sum_{p \in P^d} w^p \, \forall \, d \in N^r, \forall \, o \in N^u \qquad (3)$$

$$\sum_{p \in P} \sum_{l \in L^p} b^l \cdot q^l \cdot c^l \cdot n_u^{lp} \geq \sum_{p \in P} w^p \, \forall \, u \in N^u \qquad (4)$$

$$\sum_{u \in N^u} n_u^{lp} \geq 1 \, \forall \, l \in L^p, \forall \, p \in P \qquad (5)$$

$$\sum_{r \in N^r} n_r^{lp} \geq 1 \, \forall \, l \in L^p , \forall \, p \in P \tag{6}$$

$$y_{(i;j)} \in \{0;1\} \, \forall \, (i;j) \in A \tag{7}$$

$$n_u^{lp} \in \{0;1\} \, \forall \, u \in N^u , \forall \, l \in L^p , \forall \, p \in P \tag{8}$$

$$n_r^{lp} \in \{0;1\} \, \forall \, r \in N^r , \forall \, l \in L^p , \forall \, p \in P \tag{9}$$

$$f_l^p \geq 0 \wedge integer \, \forall \, l \in L^p , \forall \, p \in P \tag{10}$$

$$b^l \geq 0 \wedge integer \, \forall \, l \in L^p , \forall \, p \in P \tag{11}$$

$$h_{(i;j)} > 0 \, \forall \, i \neq j \in A \tag{12}$$

Objective function (1) calculates the time that all barges take for meeting the demand in containers. This time is split up in three parts, the first part is the time a barge takes waiting at the terminal. The second part is the actual handling (or service) time. The third part aggregates the sailing time.

Constraint (2) is to ensure that the barge capacity initiated in the terminal of origin and more upstream is equal or greater than the demand in the terminal of origin and upstream for every origin terminal.

Constraint (3) is to ensure that the barge capacity initiated in the terminal of origin or more upstream for all destination terminals is equal or greater than the demand for those destinations in the terminal of origin and more upstream.

Constraint (4) is to ensure that the barge capacity calling at each distinct terminal at least matches the demand in that same terminal.

Constraint (5) is to ensure that every path has at least one inland terminal call.

Constraint (6) is to ensure that every path has at least one port terminal call.

Relation (7) is to ensure that all links are either open or closed.

Relation (8) is to ensure that all inland terminals are either not called at or maximumly once.

Relation (9) is to ensure that all port terminals are either not called at or maximumly once.

Relation (10) is to ensure a positive flow of goods that consists of whole numbers of boxes. This seems straight forward but in minimisation models if not specified, might give surprising results. Bundling of freight may take place, i.e. a consignment of several boxes can be transported by several barges, but a container cannot be divided.

Relation (11) equally to (10) ensure a positive and whole number of barges sailing on the routes.
Relation (12) finally denotes the fact that terminals are located at different locations along the river and that the distance between two terminals has to be positive.

To use this optimisation model I have implemented it into a spreadsheet using OpenOffice[9] for Linux. This programme can be equipped with a solver that computes the minimisation on a numerical way. This proves to be very time consuming regarding the fact that all paths have to be taken into consideration. I have therefore sought to opt for a more theoretical approach using only six inland terminal and six port terminals, this compared to the more than thirty terminals in both segments in reality. Also here I encountered the problem regarding the time, but patient as I am, I did manage to come up with some preliminary results. Using the six inland terminals and only one port terminal I have managed to prove that indeed this model can optimise the routings. With six inland terminals and two port terminals the initial trials have shown consistency in minimising.

The ultimate goal of the modelling is to come up with a sailing scheme that reduces the overall time for the entire transportation chain. The model can theoretically do this in two different manners. The first way is to put in the demand for all products (container demand for each origin – destination pair), and to compute the most optimal routing scheme. The second way is to optimise for the different operators, and then run a new optimisation for a more aggregate level. This could be two or three but also more operators. This second way of using the model can prove the benefit of bundling consignments. As mentioned already, the current sailings are often such that barges from different operators each call at exactly the same terminals as the rival's barges. This causes a higher amount of call than necessarily needed and also decreases the call sizes. The model can show if this can be done in a better fashion, by bundling the freight.

Optimising the sail configurations although theoretically desirable does not automatically imply that it will take place in practice. The model I use, as all optimisation models, opposed to simulation models, only cover one single period in time. Trade and volumes of containers

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[9] The programme including the used solver is freely available at www.openoffice.org for all operating systems.

vary in time, the peak for the Christmas period in trading, in container haulage can for example already be seen in the summer months in Europe because of building up of stocks. Barge operators would not only want a optimal solution regarding time, they also want to meet the needs of their customers, and offer a reliable service in return. I have therefore incorporated a maximum fill rate into the model. Optimising for a certain amount of containers with a fill rate of 80% for example could ensure extra capacity meant to cope with fluctuations in demand. However one might expect that if the demand is even greater and the operator has to chose between his own cargo and the cargo of the alliance member, but in fact competitor, that he is supposed to take along with the proposed bundling, the choice will be made for the own containers. It is unknown to me how these issues are solved in the shipping alliances at sea, but this could force operators to even more enhance their capacity and therefore move even further away from the optimal solution. The eventual implementation of the model however lies far beyond the scope of this thesis.

To test the constructed model, I have computed several trials. I have added in the appendix one of these trials to illustrate the functioning of the model. Although the tests have so far been confined to just few terminals, clearly some aspects are obvious. First of all, bundling does indeed limit the amount of calls. Second, the more demands are aggregated, the more advantages there are to gain. Third, when the capacity of the barges is reached in terms of demand, the advantages of bundling is rather limited. Fourth, when limiting the number of calls in port terminals, the solution will converge with the optimal solution the higher the demands become. Fifth, especially with high demands, the models shown a substantial increase in terminal capacity as the number of calls goes down. Sixth and finally, the model as constructed is an helpful way to gain insights in the advantages and disadvantages of different sailing schemes.

Section 6

Conclusion and Findings

6.1 Conclusions

In this thesis I have researched the topic of hinterland connections of Rotterdam over the Rhine. From the historic analysis it is clear that one of the main reasons Rotterdam is home of one of the largest ports in the world has to do with the presence of the river Rhine. Historically the river was almost the exclusive domain of bulk goods, but with containerisation setting in this has changed considerably. The current shift towards more sustainable and environmental solutions in transportation will bring even more container traffic to the river on top of the already expected increase in volumes.

In hinterland and port literature the emphasis is put on the quality of the hinterland connections of a port as one of the most vital assets in port competition. Ports are more and more in competition with each other and not only the port itself is looked at, but the entire transportation chain behind the port is also taken into consideration by shippers and even carriers regarding their port choice.

In this the congestion on the waterside in the port, and the delays at the terminals forcing barges to stay for a long time in the port are not only negative for the barge operators only, but for all parties in the entire transportation chain.

In my eyes many problems encountered in barging currently resemble the struggle ocean haulage dealt with in the past. If the numbers of containers indeed will keep rising, I expect further convergence of the two types of sailing. This is already happening with the size of the barges, but this will possibly also be the case organisational wise, with the alliance structure, and sailing wise, with traffic concentration and call patterns that involve less stops.

6.2 Findings

The research question I have put forward in this thesis is the following:
How can the hinterland transport of containers by barge on the Rhine be organised in such way that both hinterland schedules and gateway seaport calls are optimised?

and the sub-questions rolling out of that are the following:
How are the current transports organised and what are the main bottle-necks?
In what way do improvements in the seaport calling patterns affect the optimality in the hinterland?
How to find and implement a solution that is acceptable according to all parties involved?

The first sub-question can be answered that the current state of transport is not adapted to the flow of containers the port is currently handling. The organisation how it stands is a direct result of historic developments of barging on the Rhine. The patterns are now such that the barges would call at a limited number of hinterland terminals (three to five) and call at up to thirteen terminals in the seaport. This path dependent organisational structure is one of the causes of the long stay in the port of the barges, which can amount up to three days.

For the second sub-question I have showed a number of solutions that reduce considerably the moves in the port. Some of the solutions did imply structural changes in the hinterland such as the introduction of hub terminals, or the usage of current terminals for transshipping the containers bound for the same Rhine section. However I have found several ways of keeping the same structure but just changing the sailing configuration. These solutions could be implemented by calling at more terminals in the hinterland, that could be within the section but also outside of the own section, or by a strengthening of the alliances, by offering slots on each others' vessels in order not to call at all terminals in Rotterdam. This last solution could as well mean more terminal visits in the hinterland. A calculation model that I constructed proves that the patterns can be changed with a gain in time keeping the same amount of vessels or even reducing it.

The third sub-question is much harder to answer, as it is difficult to judge what single parties would encounter. I have discussed the fact that different, but especially more calls in the hinterland could mean calling at evening hours at some terminals. I do think the routings can be made such that this can be avoided, however that could imply that the strict separation of the different sections in the Rhine has to be give up. But if this means that more containers can be handled and thus more earnings can be generated, I would think that this historic division could be abolished. For the terminal operators an advantage is that their capacity could go up, avoiding extra investments in infrastructure. More barges would be in use meaning a higher employment in the sector. Finally the shipper would probably have to pay a bit more for the haulage as the fill rate on the vessels will go down slightly. This on the other hand is countered by a sailing system with a higher reliability and greater flexibility.

To answer the research question, I think that with all limitations my work has at least shown that improvements can be made and that the solution with more calls in the hinterland in combination with a certain degree of slot sharing like is common in the deep-sea haulage, can provide an adequate solution to the problem that will only aggravate if nothing is done. The solution proposed here is both easy and cheap to apply but will need a whole change in the mind set of the barge world that has not really changed for the last couple of decades.

6.3 Model

I have proposed a model that can be used to optimise the sailings from hinterland terminals to port terminals. The model is based on minimising the total time for sailing, waiting and handling. This can help barge operators to optimise the routings of their barges. On top of this, the model can also be used as a handy tool to prove the benefits of cargo bundling over strict separate sailings. This bundling of freight might at least on the short and medium term be the cheapest and the most promising solution to the port congestion problem.

From tests I made with the model, although so far with just a limited amount of terminals along the river and the in port, the initial results prove the advantage of bundling over individual sailings from operators for the optimal solution.

Furthermore the model has also proven that if port calls would be limited in number, even as to one single port terminal call, especially with a high demand, the difference with the optimal solution is not very large. This is because the additional sailings are offset by a substantial gain in waiting time.

6.4 Shortcomings

I do realise that the solutions I have presented are theoretical solutions to a very practical problem. For a more practical application more insights are needed in the actual sailings and decision parameters used by the different barge operators to come to the current routings.

First, it would be nice to see what really happens on each round trip. There are, although very difficult to find, some figures on transported amounts of containers, but these are yearly aggregate figures. It would be interesting to know how the fluctuations are and to ascertain if they would alter the calling patterns greatly.

Second, the container market is a very dynamic market. Expectations in growth might be completely different in a couple of years, as well as the demand for barge transport. Even the number of terminals in the port of Rotterdam could go down as container transport might cluster completely on the Maasvlakte if the small terminal operators might vanish. This could mean that the small call sizes would become history anyway and thus taking away the current problem. Container growth if large enough can also take away the many callings per barge in the port as call sizes might go up and reduce the number of calls, but augmenting the number of barges. However the trend seen on the Rhine is that this is offset by larger barges, implying that the same or even higher call frequency has to be maintained.

6.5 Further research and recommendations

The model to optimise the calling patterns could help gain more insights in the implementation of the proposed solutions. It would therefore be important to scale up the proposed model in practice to the actual number of terminals and containers. Other programming methods and software have to be used to accomplish this within a reasonable time frame.

A number of interviews with the barge operators involved could help to see their commitment to changing the calling patterns and their willingness to cooperate in a type of slot sharing. This might also be a good way of finding out what considerations they incorporate in the decision making regarding the used routings.

Furthermore I would like to find out whether parties that now are confronted with extra costs due to the delays are willing to invest in more structural solutions in the transport chain, as they could profit from a more efficient operation. This aspect is an interesting one to be looked into, as the solutions I have searched were confined because I wanted to solve the problem without incurring extra costs.

Another approach to the problem of small call sizes is to use a mix of modalities more than is the practice currently. I have already mentioned the trials with shuttling the containers to inland locations by barge with the aim of further transport by rail. I would suggest looking into combining the transportation from inland terminal to port terminals on the different modalities. Inland terminals like port terminals are often connected to the railway network. It could be more economical both in terms of time and money to transport the small call sizes towards the port by rail or lorry and to barge only the larger consignments.

A lot of research has be done on even newer transportation modes. Notably the transport of container by pipeline has attracted the attention of some scholars. Although currently to expensive to implement for a try out, the technology shows to be promising in terms of speed, capacity and sustainability. For an immediate implementation I think that it does not meet the criteria yet, as the technology is still in its infancy, and the infrastructure that is required surpasses all current budgets. However, it might be the solution for the future.

6.6 Last words

Finally, the constructed model has shown that solutions with a limitation of calls of port terminals can indeed result in a good solution for the barging problem on the Rhine. This is especially the case when the throughput is expected to rise further. For relative high demands or inland locations close to the port, the total time spent approaches the optimal solutions with considerable gains in capacity for the terminals. This would mean a slight rise in number of barges, and thus some extra costs, however the overall reliability of the transportation system and the flexibility in terms of growth, and probable increase in employment prove that this solution could be the right one on the short and mid-term.

Section 7
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Section 8 Appendix

In this trial I have modelled sailings from upstream terminals towards the port involving four upstream terminals u1, u2, u3 and u4 and three in port terminals r1,r2 and r3.

distance table	
terminal	kilometre
u1	1200
u2	1150
u3	1100
u4	1050
r1	30
r2	25
r3	20

vessel capacity
100

sailing speed						
u1	u2	u3	u4	r1	r2	r3
15	14	15	13	13	13	13

handling speed						
u1	u2	u3	u4	r1	r2	r3
18	19	20	20	23	23	20

waiting time						
u1	u2	u3	u4	r1	r2	r3
1	0.9	0.8	1.1	8.3	7.6	8

fill rate						
u1	u2	u3	u4	r1	r2	r3
1	1	1	1	1	1	1

The distance table shows the the distance between the ocean and the different terminals. The sailing speed is in km/h and can be differentiated for the different Rhine sections between the terminals. The handling speed in in moves per hour and shows the productivity of the terminals. The waiting time is the average waiting time in hours per vessel at the terminals. The fill rate can be varied depending on the river draught, that can restrict the fill rate, but it also can be used to incorporate a safety margin regarding to the fluctuations in demand.

For this example I have used three different demands. The initial demand is taken and twice the demand and also three times the demand. This can simulate different operators with equal demand on the river that would cooperate in order to optimise the sailings.

demand 1					
	u1	u2	u3	u4	total
r1	35	67	23	8	133
r2	26	22	7	14	69
r3	77	40	53	27	197
total	138	129	83	49	

demand 2					
	u1	u2	u3	u4	total
r1	70	134	46	16	266
r2	52	44	14	28	138
r3	154	80	106	54	394
total	276	258	166	98	

demand 3					
	u1	u2	u3	u4	total
r1	105	201	69	24	399
r2	78	66	21	42	207
r3	231	120	159	81	591
total	414	387	249	147	

For these terminals the different paths or sailing options are the following:

origin	destination	paths						
		u1	u2	u3	u4	r1	r2	r3
u1	r1	1	0	0	0	1	0	0
		1	1	0	0	1	0	0
		1	1	1	0	1	0	0
		1	1	1	1	1	0	0
		1	1	0	1	1	0	0
		1	0	1	0	1	0	0
		1	0	1	1	1	0	0
		1	0	0	1	1	0	0

origin	destination	paths						
u2	r1	0	1	0	0	1	0	0
		0	1	1	0	1	0	0
		0	1	1	1	1	0	0
		0	1	0	1	1	0	0

origin	destination	paths						
u3	r1	0	0	1	0	1	0	0
		0	0	1	1	1	0	0

origin	destination	paths						
u4	r1	0	0	0	1	1	0	0

origin	destination	paths						
u1	r2	1	0	0	0	0	1	0
		1	1	0	0	0	1	0
		1	1	1	0	0	1	0
		1	1	1	1	0	1	0
		1	1	0	1	0	1	0
		1	0	1	0	0	1	0
		1	0	1	1	0	1	0
		1	0	0	1	0	1	0
		1	0	0	0	1	1	0
		1	1	0	0	1	1	0
		1	1	1	0	1	1	0
		1	1	1	1	1	1	0
		1	1	0	1	1	1	0
		1	0	1	0	1	1	0
		1	0	1	1	1	1	0
		1	0	0	1	1	1	0

origin	destination	paths						
u2	r2	0	1	0	0	0	1	0
		0	1	1	0	0	1	0
		0	1	1	1	0	1	0
		0	1	0	1	0	1	0
		0	1	0	0	1	1	0
		0	1	1	0	1	1	0
		0	1	1	1	1	1	0
		0	1	0	1	1	1	0

origin	destination	paths						
u3	r2	0	0	1	0	0	1	0
		0	0	1	1	0	1	0
		0	0	1	0	1	1	0
		0	0	1	1	1	1	0

origin	destination	paths						
u4	r2	0	0	0	1	0	1	0
		0	0	0	1	1	1	0

origin	destination	paths						
u1	r3	1	0	0	0	0	0	1
		1	1	0	0	0	0	1
		1	1	1	0	0	0	1
		1	1	1	1	0	0	1
		1	1	0	1	0	0	1
		1	0	1	0	0	0	1
		1	0	1	1	0	0	1
		1	0	0	1	0	0	1
		1	0	0	0	1	0	1
		1	1	0	0	1	0	1
		1	1	1	0	1	0	1
		1	1	1	1	1	0	1
		1	1	0	1	1	0	1
		1	0	1	0	1	0	1
		1	0	1	1	1	0	1
		1	0	0	1	1	0	1
		1	0	0	0	1	1	1
		1	1	0	0	1	1	1
		1	1	1	0	1	1	1
		1	1	1	1	1	1	1
		1	1	0	1	1	1	1
		1	0	1	0	1	1	1
		1	0	1	1	1	1	1
		1	0	0	1	1	1	1
		1	0	0	0	0	1	1
		1	1	0	0	0	1	1
		1	1	1	0	0	1	1
		1	1	1	1	0	1	1
		1	1	0	1	0	1	1
		1	0	1	0	0	1	1
		1	0	1	1	0	1	1
		1	0	0	1	0	1	1

origin	destination	paths						
u2	r3	0	1	0	0	0	0	1
		0	1	1	0	0	0	1
		0	1	1	1	0	0	1
		0	1	0	1	0	0	1
		0	1	0	0	1	0	1
		0	1	1	0	1	0	1
		0	1	1	1	1	0	1
		0	1	0	1	1	0	1
		0	1	0	0	1	1	1
		0	1	1	0	1	1	1
		0	1	1	1	1	1	1
		0	1	0	1	1	1	1
		0	1	0	0	0	1	1
		0	1	1	0	0	1	1
		0	1	1	1	0	1	1
		0	1	0	1	0	1	1

origin	destination	paths						
u3	r3	0	0	1	0	0	0	1
		0	0	1	1	0	0	1
		0	0	1	0	1	0	1
		0	0	1	1	1	0	1
		0	0	1	0	1	1	1
		0	0	1	1	1	1	1
		0	0	1	0	0	1	1
		0	0	1	1	0	1	1

origin	destination	paths						
u4	r3	0	0	0	1	0	0	1
		0	0	0	1	1	0	1
		0	0	0	1	1	1	1
		0	0	0	1	0	1	1

The model functions briefly as follows, it will assign vessels to the different paths in such way that the total time in minimised and the demands are met.

For the formulated demands, these are the calculated solutions:

solution demand 1						
u1	u2	u3	u4	r1	r2	r3
1	1	1	0	1	1	0
0	1	0	1	0	1	0
1	0	1	0	0	0	1
0	1	0	1	1	0	1

solution demand 2						
u1	u2	u3	u4	r1	r2	r3
1	0	0	0	1	0	0
0	1	0	1	1	1	0
0	0	1	0	1	1	0
1	1	1	0	1	0	1
1	1	1	1	1	0	1
1	1	1	1	0	1	1
0	1	0	0	0	0	1
0	0	0	1	0	0	1

solution demand 3						
u1	u2	u3	u4	r1	r2	r3
1	0	0	0	1	0	0
0	1	0	0	1	0	0
0	0	1	0	1	0	0
0	1	0	0	0	1	0
0	1	0	1	0	1	0
0	0	1	0	0	1	0
2	2	2	2	2	0	2
1	1	1	1	1	1	1
1	0	1	1	1	1	1
0	1	0	0	0	0	1
0	0	0	1	0	0	1

The solutions represent the amount of assigned ships and their calls. The respective times calculated for the demands are 448, 893.29 and 1333.81 hours. From these times one can conclude that indeed in bundling freight there is some to gain. In this particular example the gain in time is not spectacular. This is due to the cause that I have deliberately chosen for an option with almost full ships. The total for demand 1 equals 399 meaning that three ships are completely full with one having space for one single container left. I have chosen it in this way because if full ships can benefit from this rearranging of freight, demands that fall short of filling ships will even more benefit from bundling.

In terms of number of calls the following can be observed. For demand 1 we see 9 calls in the hinterland and 6 calls in the port with two ships calling at two different port terminals and two at just one. Demand 2 shows a solution with 17 inland calls and 13 port calls. Three ships call at one port terminal and five ships call at two port terminals. So in this solution the optimal solution in terms of time gives more port terminal calls and less inland terminal calls. For demand 3, 24 inland terminals are called at and 18 port calls are made. Of those 12 ships sailing in this configuration 8 do only call at one single terminal and call at all three and two call two different terminals.

In order to really ascertain the advantage of bundling, I will use the same demand patterns but solely allow for one single call in the port per barge. This will automatically imply that ships will have a lower utilisation in terms of capacity but will be waiting less in total. The calling patterns that emerge from that are as follows:

solution demand 1						
u1	u2	u3	u4	r1	r2	r3
1	0	0	0	1	0	0
0	1	1	1	1	0	0
1	1	1	1	0	1	0
1	0	1	0	0	0	1
0	1	1	1	0	0	1

solution demand 2						
u1	u2	u3	u4	r1	r2	r3
1	0	0	1	1	0	0
0	1	0	0	1	0	0
0	1	1	0	1	0	0
1	1	0	0	0	1	0
0	0	1	1	0	1	0
1	0	0	0	0	0	1
1	1	1	0	0	0	1
0	1	0	1	0	0	1
0	0	1	0	0	0	1

solution demand 3						
u1	u2	u3	u4	r1	r2	r3
1	0	0	0	1	0	0
1	1	1	1	1	0	0
0	2	0	0	2	0	0
1	0	1	0	0	1	0
0	1	0	1	0	1	0
0	0	0	1	0	1	0
1	0	0	0	0	0	1
1	1	1	0	0	0	1
0	2	0	0	0	0	2
0	0	1	0	0	0	1
0	0	1	1	0	0	1

To compare both options properly I have put the main differences in a table:

		vessels	inland calls	port calls	total time	sailing time	waiting time	handling time
demand 1	optimal	4	9	6	448	352.01	56.3	39.69
	single call	5	13	5	536.5	444.41	52.4	39.69
	difference	1	4	-1	88.5	92.4	-3.9	0
	difference %	22.22	36.36	-18.18	17.98	23.2	-7.18	0
demand 2	optimal	8	17	13	893.29	693.52	120.4	79.38
	single call	9	16	9	955.85	789.38	87.1	79.38
	difference	1	-1	-4	62.56	95.86	-33.3	0
	difference %	11.76	-6.06	-36.36	6.77	12.93	-32.1	0
demand 3	optimal	12	24	18	1333.81	1047.95	166.8	119.07
	single call	13	21	13	1373.02	1130.26	123.7	119.07
	difference	1	-3	-5	39.21	82.31	-43.1	0
	difference %	8	-13.33	-32.26	2.9	7.56	-29.67	0

The difference in percentage have been calculated using the mid-point method.

It is clear that the call patterns with maximum bundling along the river and calling just at one terminal in the port use more vessels. The total sailing time therefore is much higher than in the optimal solution. But the difference percentage wise in this go down dramatically with higher demand. A similar pattern would be observed if the inland terminals called at would be located closer to the port.

In terms of waiting times, the bundling of freight clearly proves to be advantageous. Here, the higher the demand becomes the greater the benefit of bundling and single calling at the port.

A major disadvantage could be the fact that more barges are required for single call patterns. However the difference in barging numbers is less with increasing demand. From a terminal point of view, the single port calling pattern means a considerable drop in barges calling at the terminals, probably increasing their capacity to accommodate further growth in the future.

If the total time is considered, the with high demands the extra time is almost to be ignored as extra sailing time is almost completely compensated with a gain in waiting time.

Concluding from this example, the model clearly shows that when the demand is almost reaching ship capacity, time gains can be made in bundling freight, although the number of calls do not necessarily go down in all cases (see demand 2 in optimal solution). I would expect that the higher the demand is, the better the solution can become in terms of calls as more possibilities occur. This is also reflected in the total amount of calls made for demand 3 in optimal solution. in total 42 calls are made where 45 would have been made if configuration 1 would have been sailed three times.

Finally this example has proven the fact that major gains can be obtained from bundling freight in order to call at less port terminals. In terms of total time there is a slight loss, however, the advantages regarding extra capacity at terminals due to a lower amount of calls could mean that in order to welcome more traffic and using the current infrastructure this type of solution is a major step forward. An extra benefit of a lower number of calls is that less delays will occur, and that those delays that will occur, would be less likely to contaminate the whole system as would be the case with multiple calling.