Intermodal Barge Transport:
Network Design, Nodes and Competitiveness

Rob Konings

Intermodal Barge Transport: Network Design, Nodes and Competitiveness

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Preface

Barge transport is known for being a slow, but reliable mode that is suitable for long-distance transport, and hence involves long journeys. The manner of accomplishing this thesis that deals with barge transport definitely bears a resemblance to this perception of the barge sector. It has been a long journey.

Already in the early 1990s Hugo Priemus, my promotor, suggested to me to think about writing a thesis, but the idea needed time to mature. Since I got involved in several projects dealing with barge transport I became more and more interested in this rather neglected mode of transport. However, my first serious thoughts about writing a thesis about barge transport more or less developed in the late 1990s, when I was participating in the European research project TERMINET, which was initiated and coordinated by OTB. This research project focussed on 'new-generation terminals' for the exchange of intermodal load units and their performance, and on the bundling of freight flows through the network. At the end of the TERMINET-project there remained challenging terminal and network issues, which inspired not only me but also my colleagues Ekki Kreutzberger and Yvonne Bontekoning to elaborate these issues in a thesis. In her thesis, Yvonne Bontekoning focussed on advanced rail-rail hub exchange facilities as an alternative to shunting yards to support the implementation of hub-and-spoke networks in intermodal rail transport. Ekki Kreutzberger's thesis covered a systematic structuring and analysis of freight bundling networks that he elaborated for, and applied to intermodal rail transport in Europe. The topic of my own thesis can be positioned as complementary to the work of Ekki Kreutzberger, since I dealt with comparable issues in the barge sector.

We were able to start our thesis projects within the framework of the multi-year (1997-2002) TU Delft research programme 'Freight Transport Automation and Multimodality' (FTAM) that was carried out under the flag of the TRAIL Research School. At that time, I was not only involved in the FTAM programme as a researcher, but I also had a co-ordinating role in this programme. I was pleased to carry out this task, but it also diverted me from focussing on the thesis work. In the years after the FTAM programme I was often tempted to get involved in contract research and it turned out to be difficult to say 'no' to colleagues when I was asked to join new projects. These circumstances have definitely also contributed to the long journey I have made to finish this thesis. But I am happy to say that my boat has now moored, and the thesis is delivered.

Although writing a thesis is something you have to do on your own, many more people were involved. So this is the moment to express my gratitude to them. First of all, I would like to thank my promotor professor Hugo Priemus. He was always there to provide me with advice and feedback on my work. His incredible speed of reading text and commenting on it has always surprised me. Considering his exceptional high productivity and my relative slow progression, it is clear that I also have to thank him for his patience. Furthermore, I greatly value him for offering new perspectives when they were needed.

Some chapters in this thesis were written as articles together with colleagues. I wish to thank Marcel Ludema, Yvonne Bontekoning, Kees Maat and again Hugo Priemus for being co-authors.

Of course, many more colleagues should be credited as they have contributed to a pleasant and inspiring working atmosphere. To those colleagues definitely belong my former roommates Ekki Kreutzberger, Kees Maat, Jan Jacob Trip and Marisa de Brito, with whom I had pleasant conversations about our work and numerous other topics. My colleagues Jaap Vleugel, Milan Janic and Bart Wiegmans kindly gave their opinion on a draft of the thesis, and gave other helpful advice.

Special thanks goes to Ekki Kreutzberger, who, being my colleague now for 20 years, introduced me to the field of transport research when I started working at OTB. I very much enjoyed working with him on many projects and I learned a lot from him.

Furthermore, I thank professor Joan Rijsenbrij and Cornelis van Dorsser for the interesting discussions I had with them about the thesis and their constructive comments.

Even when the thesis manuscript is approved there is still a long way to go before it can become a published book. I am grateful to Ineke Groeneveld, Dirk Dubbeling, Itziar Lasa and my personal ‘ICT helpdesk assistant’ Nam Seok Kim from OTB, and Conchita van der Stelt from the TRAIL Research School for assisting me in this final stage.

Last but not least, I would like to thank those close to me: my parents, who have always encouraged me and given all possible support to me to study; and, of course, my home front Angélique, Merijn and Lucas. They play a very welcome and important role in distracting the mind from work and helping to put the importance of work into perspective. So, although they are not aware of it, they were invaluable to me to achieve the completion of this thesis.

Rob Konings
Fijnaart, September 2009

1 Introduction

1.1 Transport growth and the need for sustainable transport development

Over the last decades freight transport has been growing rapidly. From 1995 to 2005 transport volume in tonne-kilometres in the European Union (of 25 countries) increased by 31% (Eurostat, 2007a). This growth of goods transport has been much larger than growth in gross domestic product (25%) and passenger transport (18% in the period 1995-2004). Moreover, its development has been much more spectacular in international transport than domestic transport. This strong growth of international transport has been fuelled by economic growth, market liberalisation and economic globalisation and, related to that, a huge increase of international trade. Worldwide trade has been growing much faster than the world economy and over the last 25 years more than twice as fast as the world economy (Clancy and Hoppin, 2006). The economic opening up of China has been a major accelerator in world trade growth and consequently has boosted freight transport. Although the worldwide financial crisis has resulted in a strong fall back in international trade and transport since 2008 the long term expectations for transport growth remain invariably high.

So far transport has been a major contributor to economic growth, but now there are serious concerns on how to accommodate future transport growth. From a policy perspective, regional, national and at the level of the European Union, the objective is to achieve a sustainable transport system, which means a transport system that meets society's economic, social and environmental needs. The bottom line of this general policy, initiated at EU level in 2001 by the European Commission (2001) in its White Paper, is a much more and balanced concern for the different impacts of transport on economic growth, social welfare and environmental protection.

This new policy has brought, among other issues, the present and future role of the road transport sector more and more into discussion. The road accounts for 44% of all freight carried in the European Union and if the sea transport mode is excluded, its share rises to even more than 70% (Eurostat, 2007a). Between 1995 and 2005 the road transport performance (in tonne-kilometres) went up by 38%, while total freight transport displayed a growth of 31% (Eurostat, 2007a), indicating an increasing share of road transport. Demand factors, such as a reduction in heavy bulk transport and the increasing importance of door-to-door and just-in-time services have undoubtedly contributed to a strong growth of road transport. The vital role of this transport mode is beyond dispute, but its contributions to traffic congestion, polluting emissions and unsafety have caused increasing concerns.

Problems arising from huge road traffic volumes become more and more manifest: trucks not only contribute to, but also experience the costs of increasing congestion on the roads as a result of capacity constraints in the infrastructure. Despite major reductions in harmful emissions of road vehicles (i.e. NO_x), the problems of CO_2 emissions and noise have increased and in the perspective of rising traffic volumes this will increasingly be a problem. Last but not least, the performance of road transport on safety remains a great concern as road transport still has the worst safety track record of all modes (Eurostat, 2007a).

If these performances of road transport are compared to rail and inland waterway transport, these alternative modes appear to have some interesting assets. As regards transport capacity, in particular the capacity of inland waterways is still considerably underused in terms of infrastructure and vessels. They could handle much greater volumes of traffic than at present (European Commission, 2001). Furthermore, rail and inland waterway transport are very safe modes of transport and when used effectively they can in many cases offer a more energy-efficient and less-polluting means of freight transport.

Given these facts and the forecasted growth of freight transport by 50% in the period between 2000 and 2020, the question arises, how, in addition to improving the sustainability of the road transport sector, rail and inland waterway transport could play a more prominent role in accommodating surface transport.

This thesis will address this question to the possible role of the inland waterway transport sector:

How can inland waterway transport increase its market share in surface transport?

In order to derive the specific research questions from this general question first a brief overview of the inland waterway transport sector is given, which explains the current role of this sector in freight transport and addresses the main challenges to increase its market share. Based on this overview the specific problem definition and main research question of the thesis are formulated in section 1.4.

1.2 Inland waterway transport in Europe: performance and characteristics

Inland waterway transport in the European Union ranks third on inland freight transport after road and rail. In 2006 the total amount of goods transported on inland waterways in the EU-27 was 503 million tonnes, which represents a 3% market share in volume. The total goods transport in tonne-kilometre (tkm) amounted 138 billion, which corresponds to a 6% market share in transport performance (Eurostat, 2007b). Although its transport performance increased by 20 billion tkm or 18% from 1970 to 2005 in the EU-15 countries (European Commission, 2003; Eurostat: http://epp.eurostat.ec.europa.eu/), its modal share has gradually declined since 1970 (Table 1.1). The growth of freight transport has been mainly absorbed by road transport, at the cost of barge transport and rail transport in particular.

Table 1.1 Modal split in inland freight transport in the European Union, 1970 – 2005, several years (% of tonne-kilometres)

		Road	**Rail**	**Inland waterways**
EU-15 countries:	1970	56	32	12
	1980	65	26	9
	1990	73	19	8
	2000	78	15	8
	2005	79	14	7
EU-25 countries:	1995	72	21	7
	2000	74	19	7
	2005	77	17	6
EU-27 countries:	1995	72	21	7
	2000	74	20	6
	2005	77	17	6

Source: Author, derived form Eurostat data

The importance of inland waterway transport in the different countries and their regions shows great variety, but the centre of gravity undoubtedly lies in the Rhine corridor (Buck Consultants International *et al*., 2004). The Netherlands and Germany accounted for 77% of the transport performance of inland waterway transport in the European Union in 2006, reaching 83% when Belgium is included[1] (Eurostat, 2007b). The modal share of inland waterway transport in these countries amounted 32%, 13% and 15% respectively (Table 1.2).

A precondition for a considerable market share of inland waterway transport is adequate demand, but above all the availability and quality of infrastructure in terms of waterways and ports. The size of the network of navigable waterways in Europe is about 52.000 km and about 50% of the total network represents the networks of France (14.900 km), Germany (7.500 km), The Netherlands (5.000 km) and Belgium (1.570 km) (De Vries, 2006), which explains the dominant role of these countries in barge transport in Europe.

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[1] France contributed for 7% of the performance of inland waterway transport in the European Union and Romania recorded 6%. The remaining 4% could be observed in Hungary, Austria and Bulgaria (Eurostat, 2007).

Table 1.2 Modal split of inland transport (road, rail, inland waterways) by country, 2006 (% of tonne-kilometres)

	Road	Rail	Inland waterways
Austria	63	34	3
Belgium	71	14	15
Bulgaria	69	27	4
Denmark	92	8	-
Finland	73	27	0
France	81	16	3
Germany	66	21	13
Greece	98	2	-
Ireland	99	1	-
Italy	90	10	0
Luxemburg	91	5	4
Netherlands	64	4	32
Portugal	95	5	-
Spain	95	5	-
Sweden	64	36	-
United Kingdom	88	12	0
Cyprus	100	-	-
Czech Republic	76	24	0
Estonia	35	65	-
Hungary	72	24	5
Latvia	39	61	-
Lithuania	58	42	-
Malta	100	-	-
Poland	70	30	0
Romania	71	19	10
Slovakia	69	31	0
Slovenia	78	22	-
EU 27	**77**	**17**	**6**

(-) not applicable; (0) negligible.

Source: Eurostat, 2008

In looking over these networks the backbone of the European waterway network consists of the two largest rivers, the *Danube,* flowing over a distance of 2850 km from Germany through Austria, Hungary, Serbia and Romania to the Black Sea, *The Rhine* (total length of 1.300 km), connecting Switzerland and important industrial regions in Germany with the seaport of Rotterdam in The Netherlands, together with the tributaries of the Rhine in Germany, i.e. the *Mosel*, *Main*, *Neckar*, the *Ems*, *Weser*, *Elbe* and *Oder* in the Northern part of Germany, the *Meuse* streaming through France, Belgium and The Netherlands, the *Seine* and *Rhône* in France and the *Rhine-Scheldt canal* linking the seaports of Rotterdam and Antwerp.[2] These waterways make major economic areas in Europe accessible by inland waterway transport (see Figure 1.1). In addition, these waterways are complemented by

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[2] In terms of transported volumes the Rhine is by far the most important waterway. It plays a part in more than 60% of the inland waterway transport in Europe. The Danube is ranked second (market share of 13%), followed by the Rhine-Scheldt canal (8%) and the Seine (6%) (Central Commission for Navigation on the Rhine and European Commission, 2008).

lower-scale waterways, especially dense in The Netherlands[3] and parts of Belgium, Germany and France, but much less elsewhere. The differences in quality of the waterways reveal itself in different maximum sizes of vessels that can be accommodated (see Figure 1.1) and hence this affects the economic conditions to offer cost-efficient barge services.[4]

The waterways have a particularly strong position in the transport of bulk goods. It has a leading role in transport of ores, coal, sand, gravel and chemical products. This can be explained by the typical characteristics of this transport mode. Barge transport is a mode that combines high mass transport capacity with low operating costs, i.e. the line haul costs (per tkm) are low. It is a mode that also provides a high level of safety, which is a favourable condition to transport dangerous goods. In addition, barge transport is known for its high reliability of transport services, because of the ample capacity of waterways that enables congestion free transport.[5] On the other hand, inherent disadvantages of barge transport are its relative low speed and limited coverage of its infrastructural network compared to rail and road networks. In order to avoid relative expensive transhipment of cargo to other modes (road or rail), the latter usually restricts the transport relations for which barge transport is considered. The transport demand for ores and coal fits very well to the features of barge transport as it consists of large long-distance (international) transport flows at a limited number of transport relations, i.e. from seaports to steel industries and power plants, that enable cheap transport by using large vessels. Transport of chemical products, petroleum products in particular, shows a more or less identical pattern. Transports are often seaport-related and involve large consignments, predominantly between refineries and chemical industrial complexes or as intermediate deliveries between chemical companies. Sand and gravel are generally not transported over very long distances, origins and destinations are much more dispersed and volumes are smaller, but still barge transport is the preferred mode here.

The strong position of barge transport in the aforementioned transport markets seems undoubtedly related to the fact that most of the transport origins and destinations are located near a water site, which makes barge transport a very cost-effective choice. Policy Research Corporation (2006) shows that on such transport relations, without pre- or post-haulage by truck, barge transport could already compete with door-to-door transport on a transport distance of even 20 – 40 km.

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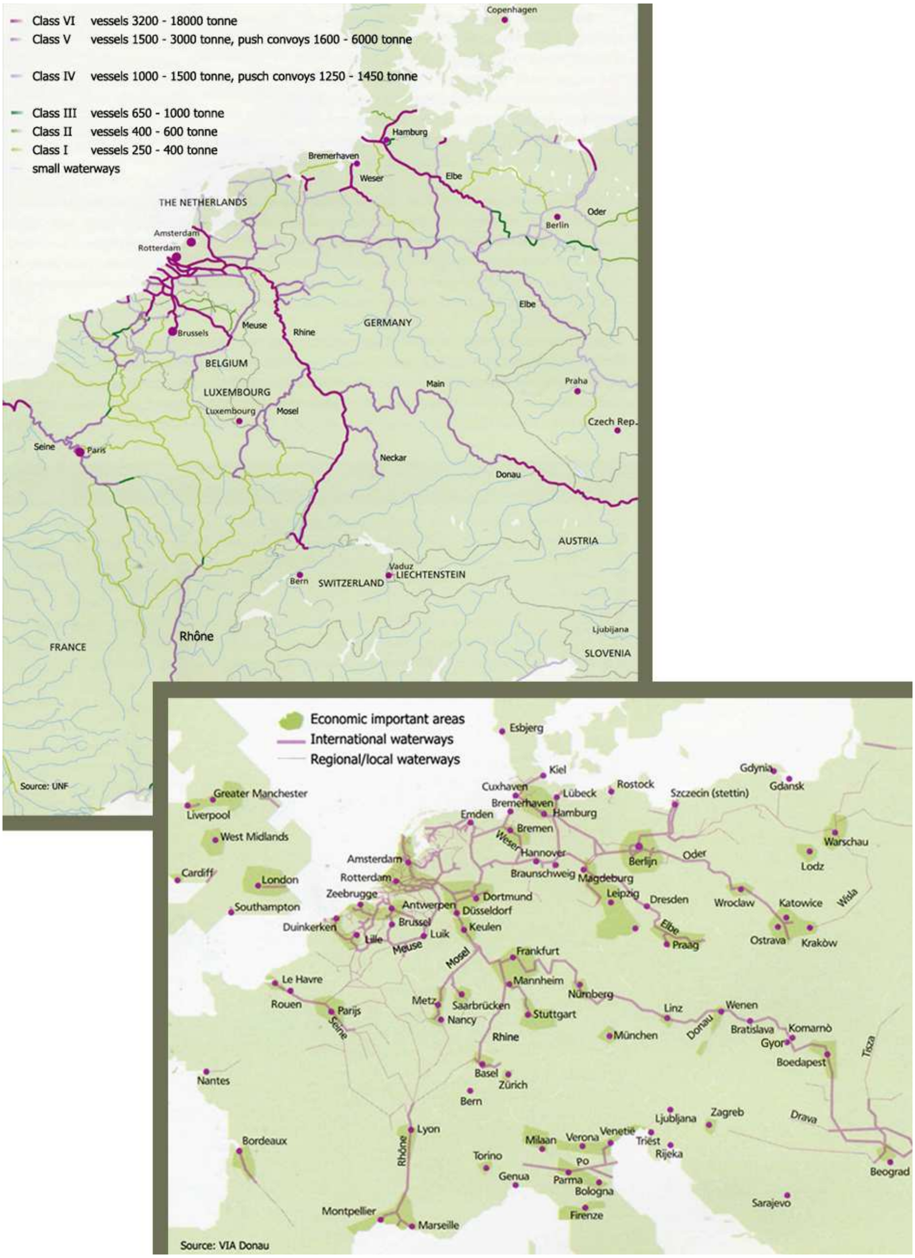
[3] The Netherlands has by far the most fine-meshed network: its length is comparable to the size of the Dutch highway network (De Vries, 2000).

[4] Although France has an extensive waterway network (the largest network of Europe), many waterways can only accommodate small vessels, which partly explains the modest role of inland waterway transport in France (see Table 1.2).

[5] De Vries (2006) estimates the reserve capacity of the Rhine at 700% and of other waterways at 100%, which indicates a large potential to accommodate future growth. However, climate change, causing more extreme variations in water levels of waterways, could be a threat for both the capacity and reliability of the inland waterway transport system in the future.

Figure 1.1 Classification of waterways in Europe and the position of major waterways in relation to important economic centres



Source: Via Donau and VNF (adapted from De Vries, 2006)

The demand characteristics and the way in which the barge sector can adapt to changes in demand seem of great importance for the possible role of the barge sector in freight transport. The overall decline of the modal share of inland waterway transport (see Table 1.1) can to a large extent be attributed to changes in the general composition of cargo towards types of goods that have historically less affinity with inland waterway transport. Economic structural changes have led to a faster growth of more highly processed goods rather than raw materials, i.e. bulk goods. On top of this shift between freight categories, in many industries new logistical concepts and changing customer demands have resulted in smaller as well as more frequent consignments of goods. These developments have strongly favoured and increased the role of road transport in the total transport system. On the other hand this changing environment has also challenged the barge sector to develop new markets.

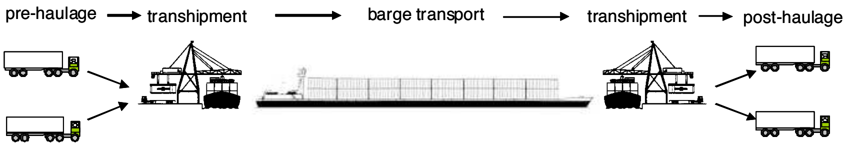
1.3 Intermodal transport: a growth market for inland waterway transport

The shrinking of the traditional markets for barge transport and the strong growth of the finished and semi-finished goods market have triggered the sector to develop new services and to improve the basic conditions of inland waterway transport. In this process the introduction of the maritime container has played an important role as it created opportunities to enter the market of transport of finished and semi-finished products.

The use of these load units has reduced the handicap of limited network coverage, i.e. the need for time-consuming and costly transhipment, and made it possible to combine the benefits of barge transport with the advantages of road transport, i.e. its high flexibility and accessibility to collect and distribute load units. This way of freight transport, using load units and a combination of modes, has emerged into a new and promising transport market, which is known as intermodal freight transport.[6]

A typical intermodal transport chain consists of a short haul by truck to pick up the load unit with goods at the shipper, a long haul by train or inland vessel and a short haul by truck to deliver the load unit with goods at the consignee (see Figure 1.2).

Figure 1.2 Representation of an intermodal barge transport chain



Source: Drawn by author

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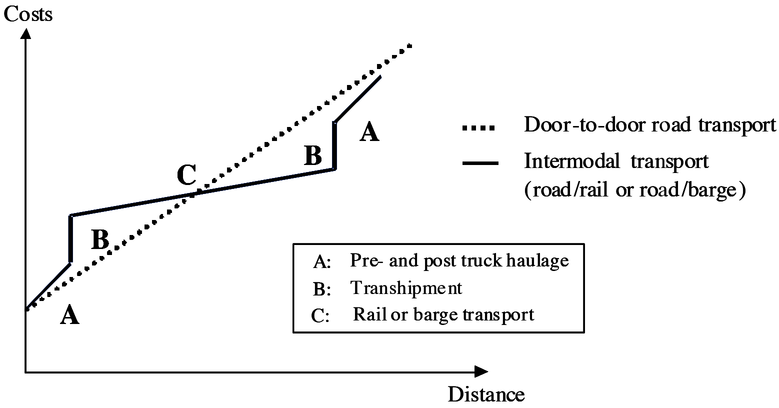
[6] Intermodal freight transport is generally defined as the movement of goods in one and the same loading unit or vehicle by successive modes of transport without handling of the goods themselves when changing modes (European Conference of Ministers of Transport *et al.*, 1997). Loading units can be containers, swap bodies and trailers.

Generally speaking the market for intermodal transport is restricted to specific segments of the transport market. It has to link zones of economic activity that can generate sufficiently large cargo flows and are sufficiently far apart that the advantages of rail or barge transport, in terms of costs per km, outweigh the additional costs of terminal operations and pre- and post-haulage per truck, when compared to door-to-door road transport. Schematically the cost structure of intermodal versus door-to-door road transport can be represented as shown in Figure 1.3.

It is evident that if either a pre- or post truck haulage is not needed the cost performance of intermodal transport immediately improves. This situation occurs in the seaport, where a container having an origin or destination overseas can be put directly on a train or inland vessel without a truck movement. This explains the relatively strong competitiveness of intermodal transport in hinterland transport as will be further discussed later on.

The transport distance is another major factor that influences the competitiveness of intermodal transport. It is often stated that intermodal transport can only compete with road-only transport on rather long distances. Van Klink and Van den Berg (1998) state that intermodal transport is generally competitive on distances in excess of 500 km. A study by Cardebring *et al.* (2000) found a minimum distance of 400 km. Alternative estimates by the Dutch government (Ministry of Transport, Public Works and Water Management, 1994) showed break-even distances for container transports having a deep sea leg (and so avoiding one truck haulage) of 200 km for rail and 100 km for inland waterway transport and for land-based container transports (having both a pre- and post truck haulage) 400 km and 250 km respectively, while Macharis and Verbeke (2001) calculated a break-even distance of 95 km for intermodal barge transport to the hinterland of Antwerp. Given different assumptions in these studies, apparently specific conditions can influence the distance at which intermodal transport can compete with road-only transport (see also Kim and Van Wee, 2009).

Figure 1.3 Cost structure of intermodal transport versus door-to-door road transport



Source: Drawn by author

Data about the total volumes in intermodal transport in Europe are not comprehensive. The transported volume in intermodal rail transport carried by the International Union of Combined Road – Rail Companies (UIRR), representing the majority of operators in this intermodal transport sector, was estimated at 4,5 million TEU (Twenty-feet Equivalent Unit) in 2003 (Savy and Aubriot, 2005) and 6 million TEU in 2006 (European Commission, 2008). The estimated volume of containers transported on inland waterways in Europe in 2003 amounted about 4 million TEU (Promotiebureau Binnenvaart Vlaanderen, Bureau Voorlichting Binnenvaart, Port of Rotterdam Authority, Voie Navigable de France, Via Donau, Inland Navigation Europe) and 4,5 million TEU in 2006 (Central Commission for Navigation on the Rhine and European Commission, 2008; Promotiebureau Binnenvaart Vlaanderen). These volumes are significant, but estimates show that intermodal (rail and barge) transport do not account for more than 5% of the total surface traffic (in tonne-km) of goods in Europe as a whole[7] (Savy and Aubriot, 2005).

The increasing role of the container in transport of goods, however, is beyond dispute. The globalisation of manufacturing and the increasing containerisation of flows, making transport of goods more cost-efficient, are major forces behind container transport growth and these trends are expected to remain responsible for a high pace of growth.[8] Forecasts for global trade volumes in 2015 still indicate a growth rate of approximately 7.5% per year, compared to an average rate of about 9% per annum over the last twenty years (Lempert, 2006; United Nations ESCAP, 2007).

Although the strong growth of container transport has its roots in deep-sea shipping most of the container flows have an inland origin and/or destination and therefore they create an important growth market for the inland transport modes and combinations of these modes, i.e. intermodal transport, as well. In addition, the use of containers is not restricted to transport in the hinterland of ports, but containers and also other intermodal load units can be an option in many other transport relations to combine the benefits of the truck with those of the train or inland vessel.

1.4 Problem definition and research questions

In looking over the development of intermodal barge transport, the volumes transported during the last two decades have substantially increased. In 1985 about 400,000 TEU were transported by barge, but since the early nineties intermodal barge transport has shown spectacular growth figures: total traffic in Europe crossed the 1 million TEU mark around 1991, the 2 million TEU mark in 1996 and the 3 million TEU mark in the year 2000 (Deplaix, 2002). The annual traffic volume in 2007 exceeded 4,5 million TEU. Apparently, the barge sector has been able to cater well to the ever-increasing demands of shippers by offering low cost container transport services with high quality in terms of frequencies and reliability. These significant numbers, however, do not alter the fact that the share of intermodal barge transport in the total surface freight transport in Europe has remained very modest (less than 3%).

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[7] Moreover, intermodal barge transport accounts for only 5% of the total river traffic (Savy and Aubriot, 2005).

[8] At the moment about 35% of all import and export goods in Europe are transported in containers, but this share is likely to increase in future to 40% or 50% (De Vries, 2006).

A closer look at the present role of intermodal barge transport reveals that the barge transport volumes are still concentrated in a rather limited number of waterway routes and in very specific transport chains: container barge transport is predominantly a *hinterland transport system* focused on the land leg of *maritime container traffic*.

It has been mostly developed between the seaports of Rotterdam and Antwerp and their hinterlands: internationally into Germany along the Rhine river and domestically, and, due to the close relation of container barge transport to deep-sea traffic, also as a mode for container feeder traffic between the ports of Rotterdam and Antwerp. The total volume of barge containers handled in these ports amounted about 5 million TEU (2,6 million TEU in Antwerp and 2,4 million TEU in Rotterdam). These volumes include about 900,000 TEU that was handled in both ports as a result of traffic between these ports.

In container hinterland traffic of the port of Rotterdam and Antwerp barge has a share of about 30%, while the market share of road and rail transport is respectively 60% and 10% (Port Authority Rotterdam: www.portofrotterdam.com; Port Authority Antwerp: www.portofantwerp.be). However, the position of barge transport differs between the specific hinterland markets. In international transport, i.e. between Rotterdam and Antwerp and Rotterdam and Germany, the barge share is 50% (Ecorys, 2008). In the Rotterdam – Germany corridor it varies between 20% for short distance destinations up to more than 70% for the upstream located regions along the Rhine river. On the other hand, in domestic container hinterland traffic of Rotterdam the barge share is just around 20% (Ecorys, 2008).

In other major container seaports in the Hamburg - Le Havre range, the role of barge is less profound. In the port of Le Havre the share of barge transport increased from 3% in 2000 to about 9% in 2007. The vast majority of these barge containers, estimated at 159,000 TEU in 2007 (Port Autonome du Havre: www.havre-port.net/pahweb.html), are transported here along the Seine to the Paris region.

In Hamburg the modal share of barge is just about 2%, which corresponded in 2007 with a volume of 95,000 TEU (Hafen Hamburg: www.hafen-hamburg.de). These barge containers find their way to the hinterland via the Elbe-river and the Elbe-Seite- and Mittelland-canal. The position of barge transport in Bremerhaven, which serves the same hinterland as Hamburg, is very similar (market share: 3%).

Regarding the smaller seaports in the Hamburg – Le Havre range the position of barge in the port of Amsterdam is striking. Its moderate barge volume of 140,000 TEU represents a market share of 43% in hinterland transport. This strong position of barge transport is related to its recent establishment as a deep sea container port. Since the deep sea carriers that call at Amsterdam in particularly serve a number of large clients in the hinterland it enables to operate barge services to the hinterland (Overtoom, 2009).

In the port of Zeebrugge, which substantially increased its importance as a container port over the last years[9], the number of barge containers and market share of barge (0,6%) are negligible (Port Authority Zeebrugge: www.portofzeebrugge.be). The bad quality of the inland waterways connecting Zeebrugge to its hinterland plays a great part here. This is in

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[9] Zeebrugge, recording a throughput of 2,2 million TEU in 2008, is the fifth largest container port in the Hamburg – Le Havre range, after Rotterdam (10,8 million TEU), Hamburg (9,7 million TEU), Antwerp (8,7 million TEU) and Bremerhaven (5,5 million TEU). Amsterdam is ranked six, but its throughput volume is significantly smaller (435.000 TEU in 2008).

contrast to the situation in Vlissingen where the waterways to the hinterland are well developed, but its development as a container port is still in its infancy.
Outside the Le Havre – Hamburg port range container barge transport in West-Europe has developed most notably in the hinterland of Marseille. Its hinterland for barge transport is the Rhone river corridor connecting the Lyon region with the seaport of Marseille. The transported volume of barge containers recorded 59,000 TEU in 2007, which counts for 6% of the total volume of container hinterland transport in Marseille (Port Autonome de Marseille: www.marseille-port.fr).

The conclusion of this brief review is that container barge transport developed successfully in some specific corridors, but there is a great challenge to further increase its market share both within and outside these hinterland corridors. The rapid growth of container throughput of ports is putting pressure on the capacity of their hinterland infrastructure, in particular the road infrastructure. The roads around the port are already often clogged and the local air quality is deteriorating (Geerlings *et al.*, 2007; Arnd, 2006). A much larger share of barge transport (and rail transport) in this hinterland traffic would improve the accessibility of the port[10], and moreover, in a more sustainable way. On the one hand this modal shift may be desirable, but also creates huge challenges for barge and rail since these alternative modes must be able to cope efficiently with additional transport volumes. For instance, the port of Rotterdam has the ambition to achieve a 45% share of barge in container hinterland transport from the port areas Maasvlakte and Second Maasvlakte in 2033[11] (Bakker en De Bruin, 2007). Its share at the present Maasvlakte area in 2007 was about 37%, while for the entire port of Rotterdam barge transport had a share of 30%. Although a growth from 37% to 45% market share in 25 years seems not spectacular, it would correspond with a tripling of the current barge volume to over 8 million TEU in 2033. Moreover, during the last five years barge transport was not able to increase its market share but rather experienced a fall back due to a bad performance of container barge handling in the seaport. Therefore increasing the role of barge transport substantially seems only achievable if the performance of the barge hinterland transport system is significantly improved.
In addition to hinterland transport of containers – and other goods where barge already has a strong position[12] – there is the continental freight transport market for intermodal barge transport, which has to be promoted. Cargo in this market has no direct relation with the seaport and since the technical necessity to transship goods between modes is therefore absent the use of load units in this market is limited.[13] Compared to container hinterland transport the continental market is even more dominated by road transport. Although barge transport does

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[10] Hinterland accessibility has also become of strategic importance for port competition, because containerisation has increased the geographical market coverage of seaports and hence transformed the hinterlands of seaports from captive to contestable regions (see e.g. Notteboom, 1997; De Langen and Chouly, 2004).

[11] The vast majority (65%) of container handling in the port of Rotterdam takes place at Maasvlakte and when the enlargement of this port area (Second Maasvlakte) is finished in 2013, this port area will get an even more dominant position in container handling.

[12] For instance in the port of Rotterdam hinterland transport of other type of goods (i.e. liquid bulk, dry bulk and other mixed cargo) is dominated by barge transport, having a market share of 50%, followed by pipeline transport (29%), road transport (17%) and rail transport (4%). The different modes have in these hinterland transport flows a more or less captive position.

[13] As far as loading units are used, the dominant type in this market is the swap body, which can be defined as a preferred unit for road-only transport and is also commonly used in intermodal rail transport, but is unsuitable for intermodal barge transport, because it can not be stacked.

play a significant role in some segments of this market (see section 1.2) there remains a large potential market here where intermodal barge transport could compete with road-only transport. However, the barriers to open up this market for intermodal barge transport are more difficult to overcome than in the market for hinterland transport of containers. First of all, there is usually a need for additional truck haulage (pre- or post-haulage) compared to hinterland transport, which is a disadvantage for the cost competitiveness to truck-only transport. Secondly, since the cargo flows in continental transport are more dispersed than in hinterland transport it becomes more difficult to achieve sufficient large freight flows to set up intermodal transport services: the bundling of freight flows is a more critical task in continental intermodal transport. Last but not least, the fact that cargo must be loaded in load units can be a detrimental factor for continental intermodal transport, because it can mean a less efficient use of loading capacity compared to the loading capacity of trucks in road-only transport.

Considering the potential contribution of inland waterway transport to more sustainable freight transport, its strategic importance for transporting containers into the hinterland of seaports and the very limited possibilities for market expansion by traditional barge transport, there is a great challenge to expand its role in the intermodal freight transport market. Based on these observations the central research question in this thesis is as follows:

> *What are the opportunities and conditions to increase the market share of intermodal barge transport in Northwest Europe?*

Increasing the market share of intermodal barge transport can be achieved by 1) improving its competitiveness in existing markets, i.e. the current transport services in the market of container hinterland transport, 2) penetration of barge transport in new geographical markets, i.e. expanding the geographical scope of container barge hinterland transport and 3) opening up the market of continental intermodal barge transport.

In order to increase competitiveness in existing markets and to develop into new market areas the cost of intermodal barge transport should be reduced and/or the quality of services improved. Since intermodal barge transport is a chain process, consisting of barge services, transhipments at terminals and pre- and post truck haulage operations, these different processes should be part of the analysis. Barge service networks and terminals form the core of an intermodal barge transport system and its performance, but the pre- and post truck haulage will also contribute to the competitiveness of the intermodal barge transport system. Moreover, its competitiveness is ultimately also related to performances of its competitors, the road transport sector in particularly.

These considerations give cause to elaborate the central research question along three main issues:

1. Network design.
2. Nodes.
3. Competitiveness in chains.

Each of these issues is addressed by a specific research question:

1. *What are the major determinants for the performance of intermodal barge service networks and which kinds of networks are most promising to increase the market share of intermodal barge transport?*
2. *What is the role of terminals in the cost and quality performance of intermodal barge transport and how can terminals contribute to a better performance?*
3. *What are opportunities and threats to improve the competitiveness of intermodal barge transport at transport chain level?*

1.5 Scope and approach

Intermodal freight transport is a research field that does not have a very long track record in scientific literature (see Bontekoning, Macharis and Trip, 2004). The rise of scientific interest in intermodal transport dates from the late 1980s when the intermodal transport industry matured and intermodal transport also started to gain policy interest. Despite this relative short space of time many studies have been carried out covering a variety of subjects related to the intermodal transport system. Besides the typical elements of the intermodal transport chain, i.e. short hauls by truck (pre- and post-haulage), the long hauls by train or vessel as well as the synchronisation of schedules of these hauls and transhipment, also other issues such as chain management and control, standardisation of equipment (e.g. load units), intermodal transport policy and planning and mode choice and pricing strategies have been subject of research.

In reviewing the literature it can be observed that in particular intermodal rail transport, but also intermodal short sea shipping transport has received much attention. This contrasts sharply with the attention for intermodal barge transport.

Considering that the different types of intermodal transport are faced with similar problems (i.e. a too low level of efficiency, profitability and competitiveness) and partly similar causes of these problems (see e.g. Konings, Priemus and Nijkamp, 2008), and given their comparable chain features (short hauls by trucks, long hauls by trains or vessels and transhipment), therefore first a brief general overview of literature addressing these chain features is given. Next, previous research that focused on the intermodal barge transport system is summarized.

Substantive research has been carried out on service network design. Generally it refers to the main tactical issues and decisions relevant for transport service providers: the selection and scheduling of the services to operate, the specification of the terminal operations, and the routing of freight (see Crainic, 2000). For instance, decisions need to be made whether to offer a direct service from a particular origin to a destination or to move the freight indirectly through an intermediate terminal and consolidate flows from nearby origins or to nearby destinations. Crainic considers the service network design issue from a methodological perspective. He presents a review of service network design modelling and mathematical programming developments for network design. A more recent overview of the analytical models for service network design in freight transportation is provided by Wieberneit (2008). Others, e.g. Woxenius (2007), Kreutzberger (2008) and Konings and Priemus (2001) have dealt with this issue in a conceptual way. Woxenius (2007) presents a general framework for consolidation and routing principles in a transport network, which is based on the following theoretical designs: direct link, corridor, hub-and-spoke, connected hubs, static routes and dynamic routes. These theoretical concepts are confronted with the rail network designs in intermodal practice. The work of Kreutzberger (2008) can be summarized as a systematic structuring and analysis of bundling networks for intermodal rail freight. In the end it looks for the directions of innovative intermodal rail bundling networks that are most relevant for improving intermodal efficiency and competitiveness. Kreutzberger also touches upon the role that terminals can play to support bundling of flows through the network. This function of terminals has been for the first time profoundly elaborated in the European research project TERMINET. In this project many studies on ideas for improving the performance of intermodal terminals have been reviewed (see Bontekoning and Kreutzberger, 1999). In addition, over the last decade a number of studies on intermodal terminals, rail terminals in particular, has been carried out (e.g. Ballis and Golias, 2002; Bontekoning, 2006; Rodrique, 2008).

The strong influence of the pre- and post truck haulage costs on the overall intermodal transport costs, and hence its competitiveness to the road-only transport, is confirmed in many studies (e.g. Morlok and Spasovic, 1994; Höltgen, 1996; Niérat, 1997, Nozick and Morlok, 1997; Black *et al.*, 2003; Resor and Blaze, 2004; Schwarz, 2006). However, its relevance stands in contrast to the rather limited amount of research devoted to this transport area (see also Kreutzberger, Konings and Aronson, 2006). Most studies have stressed the importance of the organisation of pre- and post haulage trips to influence its cost performance. For example, Walker (1992) and Morlok and Spasovic (1994) showed that substantial cost savings could be realised by either concentrating all traffic in one carrier or centralising the planning of pre- and post haulage trips. Transcare (1997) also emphasizes the effectiveness of central planning to reduce costs, but also points at opportunities to save time in the trips, which also contributes to costs reductions. In the work of Niérat (1997) pre- and post truck haulage is put into spatial perspective by the examination of the shape of the terminal service area and its size relative to freight characteristics. The ideas of Niérat have been further elaborated by Kreutzberger, Konings and Aronson (2006) in focussing on the relation between the cost performance of different kind of pre- and post haulage operations and transport landscape characteristics, i.e. the spatial and temporal pattern of transport volumes in a terminal service area. Building upon this work Konings (2008) discusses the meaning of the characteristics of a terminal service area for preferred land use policies to support the conditions for competitive intermodal freight transport.

In reviewing scientific literature on intermodal barge transport the number of publications found is limited, and only a few deal with this topic in a comprehensive way. Macharis and Verbeke (2004) composed a handbook dedicated to intermodal barge transport. In this book they give a comprehensive overview of the general position of intermodal barge transport compared to road-only transport and describe the structure and the organisation of the intermodal barge transport sector in Belgium, including the development of terminals and service networks. A major issue discussed in their book is the optimal location of intermodal barge terminals for which an analytical tool is presented. This tool called LAMBIT (Locatie Analyse Model Belgische Inland Terminals) combines a transport demand analysis and a multi-criteria analysis (see also Macharis, 2000).

The most comprehensive contribution to intermodal barge transport research that represents state-of-the-art work appears to be the thesis of Platz that was published in the summer of

2009. Platz investigated under which conditions barge transport could be more extensively and successfully implemented in continental transport chains in Europe. In assessing the market opportunities of barge transport he focussed on finding critical success and failure factors regarding innovative service development in continental intermodal barge transport. His scope of analysis included both the role of the logistical decision-makers of shippers and forwarders (micro level perspective), the transport/supply chain perspective (meso level perspective) as well as the influence of the political and institutional framework (macro level perspective). Based on studying successful and failed initiatives, Platz concludes that the following factors are crucial to implement barge transport services successfully: bundling in space and quantity (to benefit from economies of scale), backup transportation (to anticipate unreliability of barge transport when navigation is hampered), guaranteed lead times, easy intermodal transfer, complete transport-related service packages and the use of a load unit providing the capacity of a standard semi-trailer.

Another major contribution to the theoretical knowledge on intermodal barge transport and container barge networks in particular is provided by Notteboom. Inspired by the spatial development model on rail networks, developed by Notteboom (2001), an analogical model has been constructed which describes how a container barge network could develop over time (Notteboom and Konings, 2004). The model distinguishes four phases in the historical growth pattern of the European container barge network, each with distinctive characteristics related to terminal development, barge service design, container volumes and market organisation. The model basically focuses on the growth, concentration and dispersion of inland container terminals in the network in connection to seaport system development. A recent extension to these theoretical thoughts has been provided by Fremont, Franc and Slack (2009). These authors highlight the repercussions that the development of barge service networks have on the organisation of hinterlands and on interport competition of seaports. Their model is applied to an empirical analysis of the development of intermodal barge transport in the French ports Le Havre and Marseille.

The importance of organisational issues for the performance of intermodal barge (and rail) hinterland transport has been specifically addressed by Van der Horst and De Langen (2008). They emphasize the need for coordination in hinterland container transport chains. In this perpective Caris, Janssens and Macharis (2008a) did an exploratory research analysing whether cooperation between inland barge terminals may lead to denser freight flows and economies of scale to improve the performance of the hinterland network.

The notion of the importance of cooperation between actors for network design has been elaborated by Groothedde (2005). He developed a design and evaluation tool for logistics and transportation networks in which participants collaborate, based on integral logistics costs, the service requirements of the users in the network, the type of collaboration and the possible economies of scale throughout the logistics network. To validate and test his methodology he used a hub network for intermodal barge transport of fast moving consumers goods on pallets throughout The Netherlands, known as the Distrivaart-project.[14] Groothedde explicitly

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[14] The aim of the Distrivaart-project was to develop a national transport network for pallet transport by barge to distribute consumer goods between the distribution centres of factories and supermarkets. Based on the positive results of technical and economic feasibility studies a pilot started (Groothedde and Rustenburg, 2003), but this test was aborted because of insufficient cargo volumes and too high costs of pre- and end truck haulage as a result of too long trucking distances.

elaborates the role of the type and scope of collaboration between the participants as a factor influencing the feasibility of network solutions. His results show that the introduction of transaction costs in network optimisation can have a large impact on the network structure.

Caris, Janssens and Macharis (2008b) have elaborated bundling concepts for container barge networks in the port of Antwerp. In order to realise a more efficient handling of barges in the port the effect of bundling flows is analysed. Based on the network concept proposed by Konings (2005) four bundling strategies for container barge transport have been investigated and compared with the current situation with respect to the operational characteristics of the network by using discrete event simulation. With this study the authors were able to demonstrate the potential efficiency improvements in the handling of barges at sea terminals.

The improvement of handling container barges in seaports is also the subject of the thesis of Douma (2008). His research concentrated on the planning of barges visiting terminals, using the port of Rotterdam as a case of reference. Given the fact that a central planning system could be promising but has proved to be unacceptable for the parties concerned, Douma explored an alternative, so called distributed planning approach, that builds upon previous work in the APPROACH-project (Schuylenburg *et al.*, 2003; Schut *et al.*, 2004; Moonen *et al.*, 2007). This approach is operationalized through a multi-agent system consisting of barge operators agents and terminal operator agents. In this system an interaction protocol is defined based on service-time profiles which supports an efficient negotiation between barge and terminal operators and enables to improve the planning of both types of operators. Douma succeeded in improving this intelligent planning system through enabling to plan in real-time and to deal with the dynamic nature of the problem.

In addition to this software-oriented solution for handling barges in the port several studies concentrated on ‘hardware’ solutions for the problem. Major studies in which the use of innovative equipment, i.e. barges and/or cranes, have been proposed include the Floating Container Terminal (Tutuarima, 1993), Automated Container Transhipment to Inland Vessels (Onneweer, 1995), Barge Express (Wijnolst *et al.*, 1995; TRAIL, 1996), Rollerbarge (Huisman, 1995), the Floating Crane (Pielage *et al.*, 2007) and the research and development programmes of INCOMAAS (INfrastructure COntainers MAASvlakte) (TRAIL, 1995a; 1995b) and FAMAS (First All Modes All Sizes) (GEM Consultants *et al.*, 1999).

Furthermore there have been studies where orgware-oriented solutions, i.e. the re-organisation of handling barges in the seaport, have been leading. In addition to the already mentioned study of Caris *et al.* (2008), which focused on Antwerp, projects which cover this kind of ideas are Waterbakfiets (water carrier cycle) that was initiated by the study of RIL (1996) and was implemented, and the Container Exchange Point (CEP) study (RIL, 1997), which did not result into implementation. More recently studies into the so-called Container Transferium Rotterdam have been carried out (see e.g. Projectgroep Container Transferium, 2007; Froeling, 2008). This concept bears resemblance to the idea of the CEP, although the basic idea of this transferium is to give barge transport a role in the collection and distribution of containers to terminals in the port as a substitute for truck movements in order to reduce road congestion in the port. The first steps towards the development of this Container Transferium Rotterdam have been taken. Although basically it is now a terminal development project it also involves organisational issues. The importance of organizational arrangements between the actors in container barge transport to secure efficient hinterland access are further addressed by De Langen, Van der Horst and Konings (2006).

In contrast to barge handling in the seaports the handling of barges in the hinterland has been addressed less extensively. Relevant work that can be mentioned here include terminal design studies (e.g. Van den Wall Bake, 1998; Planco Consulting, 2000; Konings, 2000) and self(un)loading vessel projects (Savenije, 1997). Several of the studies mentioned above will be discussed later on in this thesis.

In looking at the previous review many of the studies related to barge transport have focussed on specific parts of the intermodal barge transport chain. This thesis aims for an integrative and broader approach regarding the performance of the intermodal barge transport chain. It addresses the relations between the performances of the links in the intermodal barge transport chain and their meaning for the competitiveness to other modes. As such this thesis research builds upon the work that was carried out in the European Research project *Terminals and Networks* (TERMINET) running from 1997 to 2000. This project focussed on innovative terminals for the exchange of intermodal load units and their performances, and on the bundling of flows through the network (see Trip and Kreutzberger, 2002; Konings and Kreutzberger, 2001; Vleugel, Kreutzberger and Bontekoning, 2001 and Bontekoning and Kreutzberger, 1999).

This thesis can therefore be defined as a system analysis of intermodal barge transport. The scope of such an analysis can range from very wide to rather narrow, dependent of the system definition (Jensen, 2008). In this thesis the system consists of the elements that enable intermodal barge transport operations, i.e. an infrastructural network of links and nodes and transport units (barges and trucks) to move containers along the links through nodes (terminals) from/to shippers/consignees. In other words, it covers the three chain activities of barge transport, transhipment and truck haulage from an *operations perspective* and considers their relevance for the improvement of the performances of the intermodal barge transport system and its competitiveness to other modes. Evidently, other subjects such as issues related to the labour market (e.g. the access to the profession and working circumstances including regulations about rest time, crew size and crew composition), the fiscal climate (e.g. investment subsidies for vessels and terminals) and technical, safety and environmental requirements and regulations for inland shipping will have impact on the competitiveness of container barge transport, but are not in the scope of this thesis.

Intermodal barge transport is defined here as combined transport of containers by inland vessels and trucks. Throughout this thesis the term ‘barge transport’ is used as a synonym for ‘inland waterways transport’. Although the thesis is focussed on container transport, the results will have a broader validity and, under certain conditions, also hold for transport of other intermodal load units (e.g. swap bodies, pallets).

From a geographical perspective this thesis deals with barge transport in Northwest Europe. That is to say, case studies which have been carried out represent cases in this part of Europe. Since the presence of waterways is a pre-condition to increase market share of barge transport and by far the most waterways are found in Northwest Europe, this region is an interesting study area. Nevertheless, the ideas developed in this thesis to improve the intermodal barge transport system are intended to have a more universal validity for parts of the world with an advanced economy. Local conditions, however, may have an influence on the viability of innovations regarding intermodal barge transport, as shown by Van Binsbergen, Van der Horst, Konings and Veenstra (2009).

Considering the central research question in this thesis the analysis of the intermodal barge transport system has been carried out mainly from an economic perspective. The thesis includes both business economic and micro-economic analyses. The transport engineering perspective is considered as a relevant discipline to design and evaluate technologies that may support improvements in the cost and quality performance of intermodal barge transport services, but this engineering approach is not profound in this study. In reviewing and addressing new technologies, i.e. terminal concepts, the conclusions and recommendations refer to the functional requirements rather than the technical design or the technical specification.

Throughout the thesis several types of research were applied and consequently a multitude of sources were used. This is partly caused by the fact that this thesis consists of selected independent research papers of which some have been written based on defined research projects (see section 1.6).
A conceptual and analytical framework for barge network design has been developed. To apply this theoretical model, cost models have been constructed to analyse the performance of different barge service networks. Regarding terminals their cost structure has been elaborated. Other cost models have been built to compare the costs of an intermodal barge transport concept with other modes and to evaluate the competitiveness of this concept. Data for these models were obtained from statistical offices, branch organisations, articles in professional journals, consultancy reports and through contacts and interviews with people from companies involved in the daily business of transport. One of the analyses that deals with the profitability of the container trucking industry has a strong theoretical approach: micro-economic theory is used to explain and illustrate the behaviour of this transport industry in practice. Finally, some of the papers can be characterized as the result of explorative research. New concepts are presented and explained, but the claims made in these papers are based upon limited empirical data or even lack any empirical test. This approach mainly applies to the papers ‘Hub-and-spoke networks in container barge transport’ and ‘Integrated centres for the transhipment, storage, collection and distribution of goods’. Certainly more research is needed here.

1.6 Outline of the thesis

The thesis consists of a collection of related research papers on the issues of network design, nodes and competitiveness. The thesis is structured according to these main lines and consists of three parts, each dealing with one of these themes. Basically each paper addresses one particular research issue, but due to the mutual relationship between network design and nodes the papers in these clusters are not entirely limited to just one issue. This holds in particular for the cluster of papers dealing with the issue of competitiveness of chains, where the perspective on the performance of container barge transport is broadened and ultimately extended to a discussion on the perspectives of the performance of its direct competitor: the container road transport industry. The fact that the papers in chapter 2 to 10 were written as independent publications also explains some unavoidable overlap in the individual chapters and some lack of coherency between the chapters. In addition, small differences occur in the spelling and reference style of the chapters. This reflects the preference of the journal in which the papers were published or were accepted for publication.

1. Network design*: What are the major determinants for the performance of intermodal barge service networks and which kinds of networks are most promising to increase the market share of intermodal barge transport?*

A service network is actually the artifact or production model of transport services. It expresses *how* transport services are operated or scheduled and routed. The volume, spatial and time patterns of transport flows play a central role in the design of a service network. This suggests that a relation exists between preferred service network and type of transport market. It is important to clarify this relationship. Understanding this relationship enables to recommend which type of barge services could be best implemented, given the characteristics of the transport market, in order to capture market share.

Chapters 2 to 4 are devoted to this issue of network design. It starts with a chapter in which a theoretical framework for barge network design is developed. This framework presents a definition of performance indicators and design variables for barge transport service networks and it demonstrates the relationship between design variables and performances. Next in this chapter this model is empirically applied in a case study to demonstrate the potential improvement in the performance of barge transport services as a result of revising the service network. The subsequent chapters covering this research issue go on to present and analyse different types of barge service networks.

Chapter 3 investigates the opportunities to develop container barge transport on small waterways and particularly addresses the option of developing the trunk-feeder service as a promising type of service network to open up new geographical markets for container barge transport.

Chapter 4 explores the conditions and implications for operating hub-and-spoke service networks in container barge transport. The typical cost, service and geographical characteristics of hub-and-spoke networks are discussed and illustrated with examples for the airline industry, which has a rich history in hub-and-spoke networks research and applications. These general features of hub-and-spoke networks are used as a framework to explore the feasibility of hub-and-spoke networks in container barge transport.

2. Nodes: *What is the role of terminals in the cost and quality performance of intermodal barge transport and how can terminals contribute to a better performance?*

This question on the one hand addresses the issue of transhipment costs and possibilities to reduce these costs, as these costs seem inherent to the characteristics of intermodal transport, while on the other hand it refers to opportunities of quality improvement in exploring possible additional functions of terminals. In elaborating this question we can deal with the role and position of an individual terminal, but the issue can also be addressed at a broader geographical level. In that case it is more appropriate to speak about nodes.

This cluster of papers, which focus on the issue of nodes, starts with a paper that discusses the possibilities to improve the handling of barges in the port of Rotterdam (chapter 5). This paper considers the node at the geographical level of the port area of Rotterdam. It elaborates the idea to improve the handling of barges through a re-organisation of the barge services.

This paper underlines the possible contribution of service networks to improve the handling of barges.

Chapter 6 zooms in at the level of the terminal processes and the performance of terminals. The future requirements of barge terminals to improve their performance are explored and innovative barge handling concepts are assessed.

The next paper, chapter 7, is devoted to a concept, which addresses the importance of a spatial and functional integration of container-handling activities with the storage and collection and distribution of goods as a way to establish a high-quality intermodal transport solution.

3. Competitiveness*: What are opportunities and threats to improve the competitiveness of intermodal barge transport at transport chain level?*

In the elaboration of this research question the possible contribution of barge service networks and terminals to improve the competitiveness of intermodal barge transport are put in a broader perspective. Ultimately the performance of the whole transport chain plays a decisive role for the competitiveness of intermodal barge transport compared to road only transport. This perspective is elaborated in chapter 8 and 9.

Chapter 8 examines at which geographical level intermodal transport services can be competitive to road-only transport. It discusses the possible degree of market coverage by intermodal transport, which touches on the issues of the density (intricate structure) of intermodal networks, the scale of intermodal terminals and the size of the terminal service areas for pre- and post truck haulage. Since pre- and post-haulage by truck is usually unavoidable, due to the limited coverage of the network of waterways, it is important to understand the relevance of these haul operations for the performance of the intermodal barge transport chain. In discussing the relations between network, terminal and pre- and post truck haulage operations the chapter deals with the question to what extent synergies or trade offs between these chain activities can emerge.

Many of the general notions on transport chain performance discussed in chapter 8 are elaborated and applied in chapter 9, in which a special intermodal barge transport concept is examined and its competitiveness to other transport systems, including road transport, is tested.

In general the competitiveness of the intermodal barge transport system will not only be determined by its own performances but by the performances of other modes as well. Other modes, such as road transport, are also continuously aiming to improve their performance to gain market share from the competitive modes. From this perspective the final paper (chapter 10) investigates the low level of price setting in the container trucking industry, which – although an external factor for the barge transport industry – is an important issue for the competitiveness of intermodal barge transport.

Finally in chapter 11 the main results of the research are brought together to answer the central research question of this thesis and to reflect on the research results. The chapter summarizes the conclusions of the selected papers, draws the general conclusions and gives an outlook on policy and research implications.

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2 Network design for intermodal barge transport

Konings, R. (2003) Network design for intermodal barge transport, in: *Transportation Research Record: Journal of the Transportation Research Board*, no. 1820, pp. 17 – 25.

Abstract

Over the last decade intermodal barge transport has been very successful in gaining market share in Northwest Europe. The barge sector has been able to cater very well to the ever-increasing demands of shippers. It is now a leading mode of transport along the major river corridors and is opening new geographical markets. These successful developments are due to the beneficial cost-quality features of intermodal barge transport compared to its main competitor unimodal road transport. However, to remain competitive in existing markets and to expand into new market areas the cost-quality features of intermodal barge transport must be improved. Network operations are important to influence the cost quality performance. Which barge network operations provide the best performance, however, depends on the transport market to be served. This relation between barge network design, transport market and the performance of intermodal barge transport is the central issue of this paper. A general framework for barge network design is presented which describes the design variables for barge networks and shows their relationship to the performance indicators of intermodal barge transport. Given the quantitative relations between the design variables for barge networks it is possible to assess the performance of different types of barge networks for different transport markets. This tool is empirically demonstrated in a case study on the Rhine river. It demonstrates that changing the network operations will lead to further improvement of the competitiveness of intermodal barge transport in this corridor.

2.1 Introduction

In a relatively short space of time barge transport has become a well-developed mode for transporting containers in Northwest Europe. Initially potential customers considered barge transport too slow, unreliable, difficult to integrate into logistic chains and only useful for long distance transport. However, the introduction of fixed and regular sailing schedules, better terminal facilities and additional services such as container storage and the organization of drayage operations changed the interest in container barge transport considerably. Since then transport volumes in container barge transport have grown steadily. The barge transport sector has further adapted itself to the demands of shippers and the specific requirements of container transport through the development of larger vessels and vessels optimally-sized for the dimensions of containers. This has further improved the cost performance and boosted the growth of container barge transport since 1985 (De Vries, 2000). Over the last decade barge transport has shown annual growth figures of 10 to 15%.

Due to the position and quality of inland waterways (rivers and canals) barge transport is concentrated in the North-western part of Europe. The Rhine river, with its tributary rivers, is by far the most important European waterway. The Rhine river connects Dutch and Belgium seaports to inland destinations in Germany and up to Switzerland (Basel) over a distance of 900 km (see Figure 2.1). The river can be partitioned in three sections, which has operational backgrounds, but also reflects some quality differences of parts of the Rhine river. The Lower Rhine, covering the river basin between Rotterdam and Cologne (about 350 km), offers the best conditions. It can accommodate the largest motor vessels or self-propelled barges as well as push tug barge combinations with six barges in a tow (185 m length by 33.20 m width or 260 m length by 22.80 m width). There are no locks and the minimum height under bridges is 9.10 m. The Middle Rhine section covers the river basin between Cologne and Karlsruhe (about 330 km). The conditions on this section are comparable to those of the Lower Rhine, but from Mainz upstream some restraints apply to the size of vessels. The Upper Rhine section, covering the area between Karlsruhe and Basel (about 200 km) shows most restrictions, because of the presence of locks (11) and much lower minimum heights under bridges, which limits the load capacity of vessels. Despite of this, vessels with dimensions of 110 m length and 11,40 m width can be accommodated. This type of vessel, which has a maximum capacity of 208 TEU (containers four high stacked), is still the most common used vessel type in Rhine barge transport, but the size range is gradually widening.

Due to the high quality of the waterway and the fact that intermodal barge transport is still mainly related to deep-sea container traffic, container transport by barge has been mostly developed between the seaports of Rotterdam, Amsterdam (The Netherlands) and Antwerp (Belgium) and the hinterland along the Rhine river. In 2001, total container traffic on the Rhine exceeded 1.2 million TEU (Twenty feet Equivalent Unit). In this river corridor the market share of barge transport varies from 20% in the Lower Rhine river basin to 35% in the Middle Rhine river basin and around 70% in the Upper Rhine river basin. These market shares reflect the increasing competitiveness of barge transport to road transport on longer distances. The barge services are predominantly line network operations, connecting several terminals in the seaports with the terminals of a river section, i.e. the Lower Rhine, the Middle Rhine or the Upper Rhine.

In addition to Rhine river transport, another major barge transport route exists between Rotterdam and Antwerp. In 1999 about 750,000 TEU were shipped between these ports.

These barge container movements, however, represent a different kind of market, since the flows are the result of feeder traffic between these mainports.
For a long time these international traffic flows have set scene for the container barge transport market, but recently new geographical markets are now also being opened up (see Table 2.1). In particular in the Netherlands barge container transport has developed spectacularly, demonstrating that barge transport can also compete with road transport on much shorter distances than previously assumed. Gradually national container barge traffic is now also being developed in Germany, Belgium and France. The spatial distribution of the inland barge terminals for container transhipment along the European rivers and canals is presented in Figure 2.1.

Table 2.1 Development of container transport by barge in major corridors/ markets (in TEU), 1994-1999

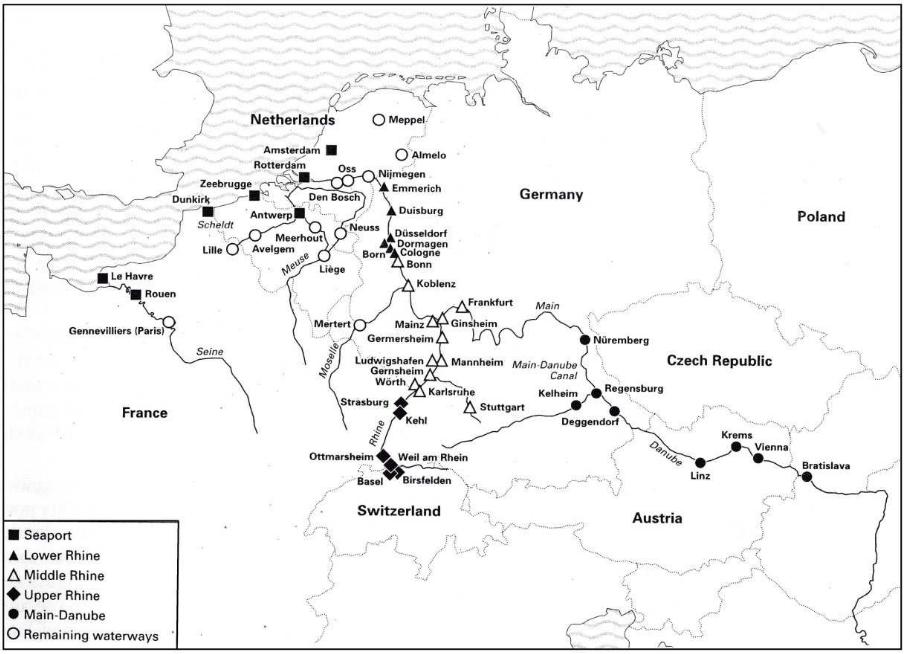
	1994	**1999**	**Growth (%)**
International Traffic:			
- *ARA ports- Rhine	600.000	1.025.000	70
- Delta Region (Rotterdam ↔ Antwerp)	400.000	755.000	90
-Netherlands – France (Rotterdam ↔ Lille)	n.a.	25.000	-
National Traffic:			
- The Netherlands	70.000	525.000	650
- Germany	n.a.	67.000	-
- France	n.a.	55.000	-

** ARA: Amsterdam, Rotterdam, Antwerp*
n.a.: not available
- : not calculable

Source: CCR; NEA/CBRB, 1995

Despite the spectacular growth figures of container barge transport there are reasons to assume that its performance can still be increased. The rising transport volumes create opportunities for improvements in efficiency, but at the same time they call for actions to maintain the high cost-quality level of barge transport. On the other hand, expanding into new geographical market areas requires the development of transport services that can compete with road and rail transport. It is here that network operations play a part. The cost and quality of transport services are closely related to the network operations within which they run. Which networks are most favourable depend on the markets to be served. Obviously, markets with concentrated large transport flows will require different network operations than markets with dispersed small flows.

Figure 2.1 Location of container barge terminals in the European inland waterway network



Source: Notteboom, 2001

In this paper we elaborate on network operations in barge transport and, in particular, we explain the relation between barge network design, the transport market and the performance of intermodal barge transport. In the second section a general framework for barge network design is presented, which describes the design variables for barge networks and shows their relation to the performance indicators of intermodal barge transport. A possible application of this framework is then demonstrated using the Rhine river as a case study. In the final section some general conclusions are drawn and some suggestions are given for some more complex network operations to be investigated in future research.

2.2 Towards a framework for barge network design

The attractiveness and success of container barge transport can largely be ascribed to the relatively low price of its services, made possible by low-cost operations. In order to maintain, and possibly improve, the cost level, two major factors need to be considered: the vessel size (scale of operation) and the circulation time of the vessel. However, the way in which they influence the costs differs. Improving the circulation time of a vessel can only lower the cost per load unit by reducing the fixed cost share, while increasing the scale of operation may result in a lower cost per load unit due to reduced fixed and variable costs per unit.

The scale of operation and the circulation time of a vessel are not independent decision variables for a barge operator, but are related to quality features, such as the frequency and transit time of services. In fact, barge operators have to trade-off costs and quality features as well as considering relevant external conditions, such as the dimensions and quality of waterways. We will briefly explain the trade-off issues between costs and quality in relation to the vessel size and the circulation time.

2.2.1 The vessel size

In discussing the advantages and disadvantages of increasing the scale of operation, we will refer to three vessel sizes corresponding to loading capacities of respectively 90 TEU, 208 TEU and 398 TEU. These vessel sizes are considered as representative of medium, large and very large vessels in container transport.

The vessel size is determined by:

- Available transport volume.
- Cooperation / opportunities for bundling.
- Minimum service level: frequency of services.
- Fit of circulation times to sailing schedules.

Available transport volume

To recover the costs of a service a sufficient loading degree is required. A reduction of the loading degree, therefore, may have a significant influence on the cost-effectiveness of a service, due to the cost structure of barge transport. As most of the costs are fixed, a reduction in the loading degree will have a minimal effect on the costs, but a significant effect on the revenues (see Figure 2.2). Operators estimate the break-even loading degree to be 75%. This estimation is based on the present barge operations, which are characterized by rather long circulation times of vessels. If circulation times are improved the break-even loading degree will decrease.

Figure 2.2 Relationship between costs, revenues and loading degrees in barge transport

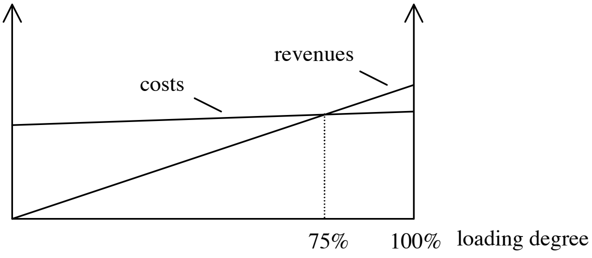
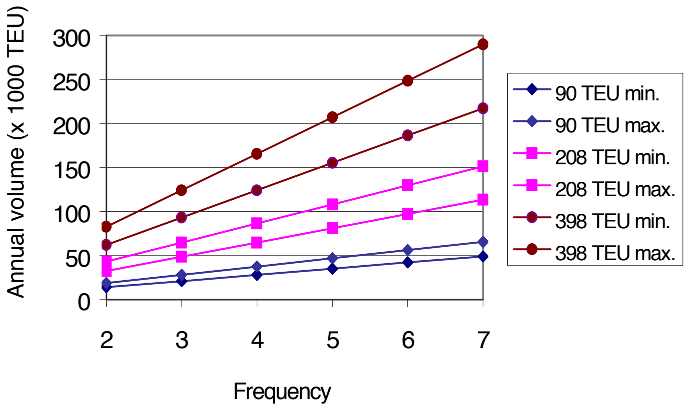


Figure 2.3 explains the relationship between vessel size and the annual transport volume for different transport frequencies. It shows both the annual transport volume required to achieve a loading degree of 75% (as a minimum value) and the maximum transport volume, based on

a loading degree of 100%. The conclusion is that, if available transport volume is small, it is better to use smaller vessels.

Figure 2.3 Relationship between vessel sizes, annual transport volumes and transport frequencies (75% loading degree = minimum; 100% loading degree = maximum)



Cooperation / opportunities for bundling

The required transport volume for using larger vessels could be achieved by operational co-operation between barge operators. These collaborations have already taken place, especially in barge transport on the Rhine river. They are based on a vessel-sharing agreement, in which the barge operators can preserve their commercial corporate identity. In addition to this way of bundling flows, flows which feeder the trunk route may support an increase in the scale of operation.

Minimum service level: frequency of services

As can be seen in Figure 2.3, a theoretical trade-off seems possible between vessel size and transport frequency for a certain available transport volume. However, since shippers wish to have sufficient sailings per week a certain minimum frequency needs to be offered. Therefore, growth of transport volumes can be used first to increase the number of sailings and later on to increase the size of the vessel. This is a well-known strategy in the barge transport sector (Konings and Kreutzberger, 2001).

If we assume a service level of five services per week, which conforms to the shippers' requirements, annual transport volumes above 100,000 TEU might provide an argument for using a 398 TEU vessel rather than a 208 TEU. However, as Table 2.2 shows, it might be advantageous first to increase the transport frequency, because the difference in transport volume required between a 208 TEU vessel and a 398 TEU vessel is substantial.

Table 2.2 Transport volumes (in 1,000 TEU) for different vessel types with different frequencies (loading degree: 95%)

Frequency per week	208 TEU vessel	398 TEU vessel
5	100	200
6	120	235
7	145	270

Fit of circulation times to sailing schedules

In addition to volumes and frequencies there is another consideration for choice of vessel size, i.e. the circulation time also known as roundtrip time. The circulation time is defined as the time between the departure of a barge at a terminal and the following departure of the same barge from that terminal. There is a preference for circulation times, which are a multiple of twenty-four hours, in order to keep regular sailing schedules i.e. the same departure time for every service. Circulation times usually include some idle time for barges to absorb possible delays and to keep the multiple of a twenty-four hour pattern. If the requirement for regular sailing schedules was dropped and so-called 'future times' operations could be introduced, the idle time within a circulation could be reduced. Consequently, the circulation time would decrease and the number of annual roundtrips could then be increased (see also Kreutzberger, p. 87 a.o.). The way in which a sailing schedule incorporates possible idle time of barges in a circulation time determines the reliability of barge services.

Increasing the size of a vessel will increase the total loading/unloading time and therefore a large vessel will spend a greater proportion of time at the terminals. This may especially arise when more terminals need to be served in order to get the larger vessel filled. The circulation time will increase and it might become unfavourable to maintain an efficient sailing schedule. As a consequence, the number of possible roundtrips may decrease, which would have a negative effect on the transport costs per load unit.

2.2.2 Improvement of the circulation time of vessels

A reduction in the circulation time of vessels results in:

- cost savings because of better utilization of vessels. If more roundtrips can be made within the same period of time, the fixed costs are spread out over more transport services, therefore costs per load unit decrease. Since fixed costs are a major cost component in barge transport, this is an important factor in reducing costs.
- improvement in the transit time of vessels. If the circulation time is shorter, the transport time of a barge service also reduces.

In general the circulation time of a vessel depends on:

- sailing distance
- sailing speed
- duration time at the seaport
  - number of calls
  - average call size
  - handling time at terminals
  - waiting time at terminals

  - opening times at terminals
- duration time in the hinterland
  - number of calls
  - average call size
  - handling time at terminals
  - waiting time at terminals
  - opening times at terminals
- agreements about time windows for loading and unloading

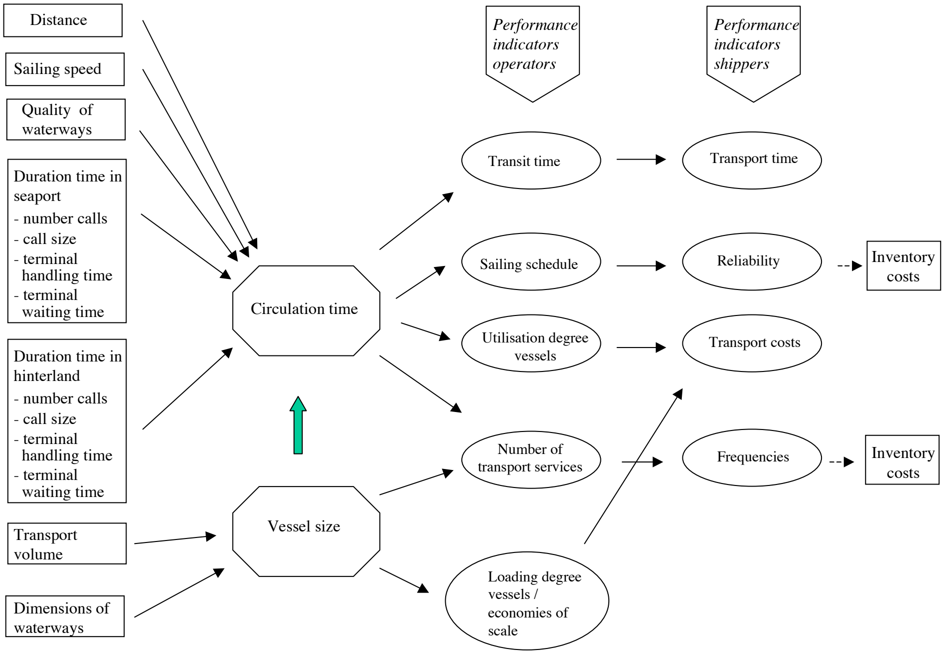
Sailing speed and distance are important for the barge operator and the client of the barge service, the shipper, because together they determine the time required by the barge service. In reality, the possibilities of changing these variables are limited. It is unfavourable to increase the sailing speed substantially, because of an exponential increase of fuel costs.

Duration time at the seaport and duration time in the hinterland are determined by the type of services, such as point-to-point services or line-services, because the type of service determines the number of calls and indirectly also the call size. On the other hand the duration time depends on the characteristics of the terminals involved – the capacity and quality of the equipment and opening times. The vessel size is also relevant here, because it influences the loading/unloading time of vessels.

Agreements about time windows for loading and unloading enable terminal operators to plan their handling activities better and therefore get optimal utilization of terminal equipment. If vessel operators cannot meet these agreements, the duration time at a terminal may be extended. This is primarily a problem for seaport terminals such as in Rotterdam, where the planning of handling barges is still problematic. That means, if delays occur at one terminal in the port they will be transferred to the next.

Figure 2.4 presents a framework of the factors that influence the performance of intermodal barge transport. This framework shows the determinants for the main factors, – the vessel size and the circulation time of vessels – and shows their relationship to the performance indicators of intermodal barge transport from both the barge operators' and shippers' perspective. This general framework can also be used as a tool to explain and evaluate the relation between barge network design, the transport market and the performance of intermodal barge transport. A simple application of this tool is empirically demonstrated in the next section.

Figure 2.4 Framework for barge network design



2.3 Case study Rhine river: Rotterdam – Duisburg

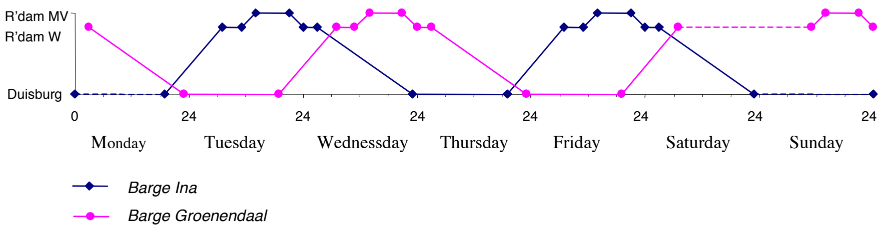
In order to demonstrate possible improvements in the performance of barge transport by redesigning barge networks, this section presents the results of a case study on Rhine river transport, concentrating on the link between Rotterdam and Duisburg.

2.3.1 Data and results

The data used reflects the situation before the DeCeTe and ECT barge terminals were merged. Located side by side in Duisburg, DeCeTe and ECT operated as independent terminal and barge operators. DeCeTe offered barge services between Duisburg and Rotterdam five times a week, Antwerp twice a week and Zeebrugge once a week. The services between Duisburg and Rotterdam were sold as direct services, i.e. point-to-point services, but vessels had to call at several terminals in Rotterdam. Services between Duisburg and Antwerp also called at Rotterdam. For all the Rotterdam and Antwerp services, DeCeTe used three vessels with capacities ranging from 120 TEU to 208 TEU. In addition, ECT offered four services per week between Duisburg and Rotterdam, with calls at Rotterdam Waalhaven and Rotterdam Maasvlakte.

In general, both DeCeTe and ECT barge services had more or less the same sailing schedule: barges arriving at Duisburg in the morning and departing from Duisburg in the evening. By way of illustration, Figure 2.5 shows the sailing schedule of the ECT services between Duisburg and Rotterdam. Two vessels, Ina (capacity 81 TEU) and Groenendaal (208 TEU capacity), were used to offer a service four times per week.

Figure 2.5 Sailing schedule for barge services between the ECT-Duisburg terminal and Rotterdam



Although the waterways between Rotterdam and Duisburg have hardly any restrictions on vessel size, the largest vessels that were deployed by ECT and DeCeTe were 208 TEU vessels. The transport volume between the seaports and the terminals of DeCeTe and ECT, 90,000 and 30,000 TEU respectively in 1999, could very well explain the preference for smaller vessel sizes. Of course, some form of operational co-operation could have been beneficial, but did not occur. DeCeTe benefited to some extent from opportunities to bundle flows, since it combined services to Antwerp with those to Rotterdam. However, ECT envisaged an annual transport volume of about 180,000 TEU by 2005, which, combined with DeCeTe's volume (90,000 TEU), would provide opportunities to increase the scale of operation whilst maintaining service frequencies that conform to the shippers' preferences (see Figure 2.3).

As Figure 2.5 shows the sailing schedules are based on vessels having a circulation time pattern of 72 hours. This leaves much room for improvement considering that the actual sailing time is about 33 hours for a roundtrip and the actual loading/unloading time for a 208 TEU vessel is about 16 hours (8 hours in Rotterdam and 8 hours in Duisburg). Therefore if barge services could be changed to pure point-to-point services with minimal waiting times of 1 hour at the terminal and including a sailing margin of 1 hour per direction, a circulation time of 53 hours could be achieved for a 208 TEU vessel. These kind of network changes would result into a circulation time of 44 hours for a 90 TEU vessel and 68 hours for a 398 TEU vessel. For regular sailing schedules, i.e. the same departure time for every service, the vessel size that leads to a cycle time close to a multiple twenty-four hours will be most attractive, because there will then be minimal idle time. For this particular scenario, the 90 TEU and the 398 TEU vessel are therefore the most favourable sizes (see Figure 2.6). The 208 TEU vessel would give a very unfavourable cycle time, because of a large amount of idle time. Under these conditions there would be an incentive on the Rotterdam – Duisburg link to increase the scale of operation from 208 to 398 TEU vessels. Two of these large vessels could offer the same service level of four services per week as the two smaller vessels currently being used by ECT. However, the transport volumes required for these 398 TEU vessels need to be present for maximum efficiency.

To demonstrate the possible cost savings of increasing the scale of operation on the Rotterdam – Duisburg link, we calculated the costs for different vessel sizes based on a sailing schedule of two roundtrips per week (see Figure 2.7). From these calculations we can conclude that doubling the vessel size will reduce the costs per TEU by 20 – 30%.

Figure 2.6 Relationship between vessel size and cycle time on the route Rotterdam – Duisburg, for an 'ideal' situation: pure point-to-point services and minimal waiting times at terminals

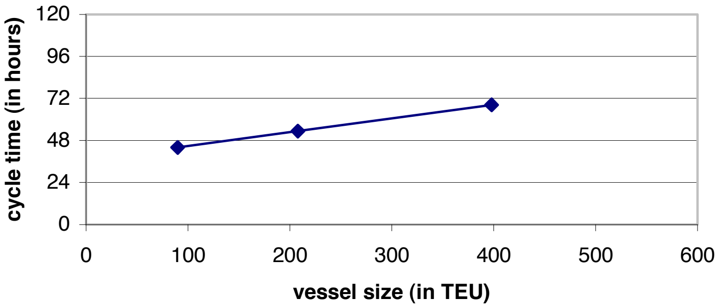
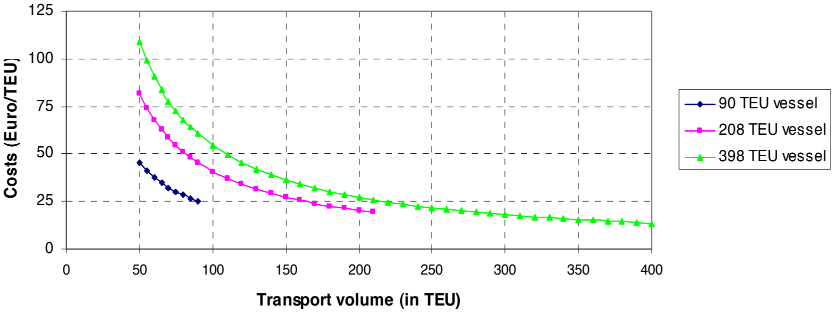


Figure 2.7 Indicative costs per TEU on the route Rotterdam – Duisburg for different vessel sizes with varying transport volumes (i.e. loading degrees); circulation time: two roundtrips per week



Considering the lengthy circulation time of 72 hours in the existing operations, we examined its components in more detail to evaluate the real possibilities for improvement. We observed that the duration times in the ports of Rotterdam and Duisburg are relatively long (20 hours) compared to the effective time required for loading/unloading a vessel (8 hours). As we discussed, these time windows are a result of the desire to maintain the regular daily and weekly service pattern, but other circumstances also play a part. The duration time in Rotterdam includes a transfer between the terminals in the Waalhaven and Maasvlakte area (which takes 6 hours altogether) and, in addition, it offers time buffers for delays at terminals, which often happen. This problem of delays is increased by the fact that, usually, several terminals have to be called at. The negative impact on the circulation time of vessels of calling at a large number of terminals in the Rotterdam seaport is very well illustrated in Table 2.3. The large number of calls leads to small call sizes, increases waiting times and therefore extends the duration time in the port. As Table 2.3 shows, these facts hardly changed over the decade 1988-1997.

Table 2.3 Handling characteristics of inland vessels in the port of Rotterdam

	Findings of GHR (1988)	**Findings of RIL/CBRB 1997)**
Average nr. of calls per trip	7,6	8,1
Average nr. of moves per call	16,6	16,5
Average time in the port	29 hrs	28 hrs
Average call-time per trip	12 hrs	13 hrs
Average move time per trip	-	7,5 hrs
Barge on time	30%	19%
Barge too early	-	43%
Barge too late	-	38%
Moves per call	53% less than 5 containers	43% less than 6 containers

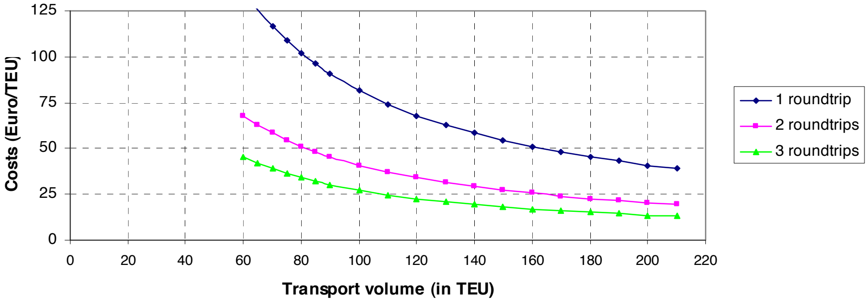
Source: Savenije e.a., 1998

The long duration time in Duisburg resulted from the desire for a regular service schedule and the aim to adjust the arrival and departure times of vessels to the preferences of shippers, i.e. receiving containers in the morning and dispatching containers in the late afternoon. Of course this results in long periods in which the vessels are idle, and this has a negative impact on the circulation time of vessels. The large time-window for unloading and loading in Duisburg was, to some extent, to be used for transhipping directly from truck to barge and so avoiding temporary stacking of containers on the quay and reducing the number of terminal handling activities.

Due to the problems of calling at many terminals in the port of Rotterdam, we studied the effects of limiting the number of calls per vessel and changing the services into point-to-point services – direct services between Duisburg and Rotterdam Waalhaven and Duisburg and Rotterdam Maasvlakte. It revealed that the average vessel circulation time could be reduced by around six hours and the transit time of services to and from Rotterdam Maasvlakte on average by three hours. These results appeared insufficient to make these circulation time improvements effective for 208 TEU vessels, unless the performance of the terminals is improved or the regular sailing schedules are dropped (see Konings, 2000).

To illustrate the effects different circulation times have on costs, calculations were made, varying the number of roundtrips per week (Figure 2.8). Increasing the current number of two roundtrips to three was found to lead to cost savings of 10 to 30%.

Figure 2.8 **Indicative costs per TEU on the route Rotterdam – Duisburg for different number of roundtrips per week and varying transport volumes (i.e. loading degrees); vessel type: 208 TEU vessel**



2.3.2 Case study conclusions

From the results the following conclusions were drawn:

- Increasing the scale of operation on the trunk route Rotterdam – Duisburg could reduce the costs by 20 – 30% per TEU. However, to satisfy a major condition of increasing the vessel size – sufficient transport volume to maintain the current service level – would require co-operation between the barge operators DeCeTe and ECT and a further growth of their joint transport volume.
- A reduction of the circulation time of vessels, which enables a vessel to make more roundtrips a year, appears to be a possible strategy to save on the fixed costs of barge transport, but can only be achieved under specific conditions:
  - In case of point-to-point services and minimum waiting times at terminals, the circulation time of a 90 TEU vessel could be improved to make an additional roundtrip per week (three roundtrips instead of two). The sailing cost savings amount from 10 to 30%.
  - Due to the time spent on the network between Rotterdam and Duisburg, comparable circulation time improvements for the 208 TEU vessel are only possible if the terminal handling time of vessels could also be reduced. This requires additional cranes and/or a new type of cranes with higher performance.
- The waiting times at terminals in the seaport Rotterdam are a very serious bottleneck to improving circulation time.
- The actual cost savings of improving the circulation time of vessels depend on the match within the sailing schedule of the vessel. However, as long as barge operators are confronted with highly unreliable, and therefore varying, duration times at terminals in Rotterdam, it is more interesting to aim for pure point-to-point services between Duisburg and Rotterdam, instead of considering additional (intermediate) terminals to optimize the circulation time within the sailing schedule.
- An additional advantage of improving the circulation time of vessels is a reduction in transit time. However, the real benefits of these savings and the possible time savings are limited in the current sailing schedules.

2.4 General conclusions

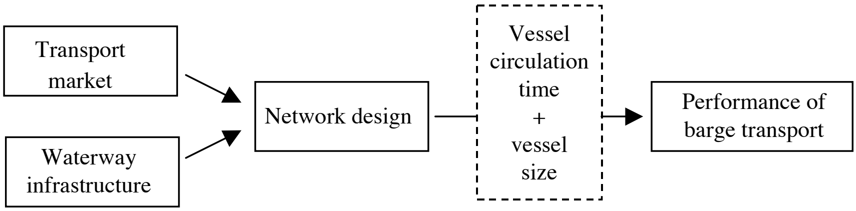
In this paper we presented a conceptual model for barge network design which describes the design variables for barge networks and their relation to the performance indicators of intermodal barge transport from a shippers' and operators' perspective.

With this model we explained that the vessel size and the circulation time of vessels are major factors for this issue. The vessel size and the circulation time directly influence the cost and quality performance of barge transport. However, these factors are determined by the network design, the transport market – to be characterized by transport volume and distance – and the waterway infrastructure reflected by the dimensions and quality of waterways, e.g. width and depth of waterways and the presence of locks and bridges.

The relations between the variables in this model seem simple, but there are several interdependencies which makes it more complex. Firstly, the model shows the existence of trade-offs between the cost and quality of barge transport services, which are the result of a relation between the vessel size and the circulation time of vessels. Secondly, the network design, the transport market and the waterway infrastructure are not independent variables, but the decisions on network design are conditioned by the characteristics of the transport market and the waterway infrastructure.

To generalize these findings, the framework for barge network design as we presented in section 2 can be transformed to a more general and summarizing diagram (Figure 2.9).

Figure 2.9 Generalized framework for barge network design



In the case study presented in this paper we considered a rather simple network: a line service, i.e. a service between Duisburg, Rotterdam Waalhaven and Rotterdam Maasvlakte, which we transformed into point-to-point services, i.e. Duisburg – Rotterdam Waalhaven and Duisburg – Rotterdam Maasvlakte. This network adjustment showed considerable potential benefits, provided that some conditions are fulfilled.

In a broader perspective some more complex network concepts are conceivable. These concepts can influence many transport services on the Rhine and therefore can have a large impact on the performance of barge transport.

One of these concepts is uncoupling of the collection and distribution services in the port of Rotterdam from the trunk haul services to the hinterland. This implies that Rhine barges only have to call at one terminal in Rotterdam, so reducing their duration time in the port and consequently improving their circulation time. In the past some solutions for this typical network problem of the port of Rotterdam have been proposed, but have not been implemented (Tutuarima, 1993; RIL, 1997). In view of growing barge traffic in Rotterdam and its effect on terminal waiting times, it would be worthwhile to reconsider such a network innovation. Another interesting innovation can be the development of a limited number of hubs (two or three) – possibly one for each Rhine region – which have direct services to Rotterdam and which are feedered by services to/from the other Rhine river terminals. Alternatively, there can be one main hub, which is feedered by a limited number of point-to-point services to terminals upstream the Rhine river, that due to waterway restrictions can only be reached by smaller vessels. Such a network design can combine the scale advantages to the main hub with improvements of the circulation time of vessels to the hub and the terminals located upstream the Rhine river. Of course in these kind of network configurations, which imply an intermediate exchange of load units between barges, terminal operations become more decisive for the integral cost and quality performance of barge services (Konings, 2000).

The model we presented here can be a useful tool to explore and evaluate some of these promising network reconfigurations for Rhine barge transport. Of course the model can also be applied for barge network design for other transport markets.

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3 Development of container barge transport on small waterways: from increasing scale to increasing scope

Konings, R. (2004) Development of container barge transport on small waterways: from increasing scale to increasing scope, in: *Transportation Research Record: Journal of the Transportation Research Board*, no. 1871, pp. 24 –32. Copyright © Transportation Research Board of the National Academies.

Abstract

During the last decades the scale of operation in container barge transport has continuously increased in Europe. Large vessels producing lower operational costs per load unit have been the major cause of this trend and, since low costs have traditionally formed the competitive edge of inland shipping, this development has become a self-fulfilling process. Exploitation of these scale advantages has contributed to a strong position of container barge transport on large waterways in Northwest Europe. Along these transport axes barge transport has gained a substantial market share. The opportunities to develop container barge transport on small waterways have been highly overlooked and its development has also been discouraged by transport policies. However, to further increase the market share of container barge transport would require a penetration of new geographical markets. In this process the use of small waterways plays an important role. In this paper the possibilities to develop and improve the competitiveness of container barge transport on small waterways are discussed. In discussing these options special attention will be given to the role of adapted network operations as one of the promising strategies. It is shown that both technical and logistic innovations can provide interesting opportunities to develop container barge transport on small waterways.

3.1 Introduction

In a time span of just thirty years container barge transport has developed into a full mature industry in Northwest Europe. Relative low cost operations, which are a traditional distinguishing feature of barge transport, formed the initial trigger to start container barge transport services. Since then the barge sector has continuously adopted new logistic concepts (including the provision of additional services) to further increase the attractiveness of container barge transport and with great success. A major element in the development strategy has been a continuous increase in the scale of operation in order to improve its comparative cost advantage.

Initially vessels were operated with a capacity ranging from 24 to 54 TEU. In this period, the early seventies, vessels were not well equipped for container transport yet. Dimension of vessels were not attuned to the dimension of containers and vessels could only load two layers, because a movable cockpit did not exist. However, supported by increasing transport volumes in a short time of span the vessel size increased and container dimensions became decisive for the dimensions of new vessels to be built. In the mid eighties still many conventional vessels (80 x 9,5 metres; capacity: 70/80 TEU) were used, but soon the maximum allowed size of a Rhine vessel (110 x 11,4 metres) having a capacity of 208 TEU became the most common type of vessel for container transport on the Rhine river. In addition to conventional vessels, also push barge-vessel units (a motor vessel with one push barge) were introduced in the early nineties, raising the potential vessel capacity to even 400 TEU (De Vries, 2000). This trend of increased scale of operation has been more recently (since 1998) reinforced by the emerge of some large vessels (135 x 17 metres; capacity: 398 TEU). In this category of very large vessels there are several vessels forthcoming now. In future even much larger vessels are expected to come. Serious ideas exist for a vessel of 135 by 20 metres measuring 476 TEU (4 layers) or 560 TEU (5 layers). This vessel may be introduced in the market in 2006. In the long term even vessels having 800 TEU capacity seem conceivable.

It is without doubt that cost advantages due to increased scale of operations has attributed substantially to the current strong position of container barge transport. In both the seaports of Rotterdam (The Netherlands) and Antwerp (Belgium) barge now has a share of about 35% in hinterland transport. These market shares are the result of a very strong position of barge transport at a rather limited number of waterway routes, the Rhine river in particular (see also section 4). There is still room for improvement on these major axes to gain market share and to expand the natural catchments area of barge transport along these axes. However, to further increase the market share would also require an expansion of the geographical scope of container barge transport. This is an interesting option to develop hinterland transport, but would be even more useful to open up the market for intermodal barge transport of continental cargo.

The density of waterway networks is a basic requirement for a potential large geographical coverage, but it also requires possibilities to develop barge transport on small waterways in a competitive way. Consequently small vessels have to play a part in it.

In this paper we will discuss the possibilities to develop and improve the competitiveness of container barge transport on small waterways. The paper is organised as follows. The next section gives a definition of a small waterway and presents the role of small waterways in the inland waterway network in Northwest Europe. Then the current market position of small vessel is discussed in view of internal and external developments affecting the barge sector. The competitiveness of small vessels is discussed from a sector-wide perspective. After that the present role of small waterways in container transport is described. Based on these observations options to expand and improve container transport on small waterways are discussed. In this overview special attention is given to the strategy of adopted network operations. The paper ends with a brief evaluation of the different strategies.

3.2 Position of small waterways in the European inland waterway network

In West-Europe there is ample supply of inland waterways. The total length of the inland waterway network in the countries of the European Union amounts nearly 30.000 km, which is in sharp contrast with Central Eastern Europe measuring a waterway network of just 9.000 km. Great differences also exist between the lengths of national networks. Table 3.1 presents the top 4 of West European countries. France (8473 km), Germany (6391 km) and The Netherlands (5046 km) have by far the largest waterway networks. It is also striking to notice that the Dutch network is relatively very dense, which gives the inland shipping sector in The Netherlands a comparative advantage.

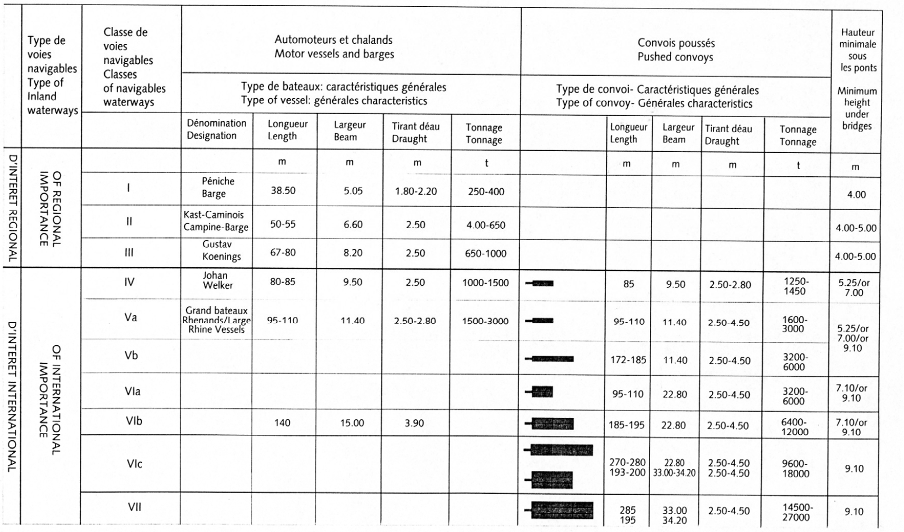
Table 3.1 Length and density of inland waterway networks

Country	**Total length (km)**	**Length per 100 km^2**
France	8473	1,1
Germany	6391	2,1
The Netherlands	5015	12,2
Belgium	1540	5,0

Source: AVV Transport Research Center, Ministry of Transport, Public Works, and Water Management

In addition to a variation in length of networks there is also a wide range in quality or navigability of waterways between and within European countries. Differences in navigability are being indicated by an international standard waterway classification system developed by CEMT (Commission European de Ministres des Transport). The class of a waterway is determined by the horizontal dimensions (length, width) of a vessel or push barge combination. In view of the draught of a vessel, which relates to the horizontal dimensions of a vessel and which might be subject to local conditions, each waterway class can also be identified by a characteristic tonnage. The classification system covers seven classes (see Table 3.2).

Table 3.2 CEMT classification of waterways



Type de voies navigables Type of Inland waterways	Classe de voies navigables Classes of navigables waterways	Automoteurs et chalands Motor vessels and barges					Convois poussés Pushed convoys					Hauteur minimale sous les ponts Minimum height under bridges
		Type de bateaux: caractéristiques générales Type of vessel: générales characteristics					Type de convoi- Caractéristiques générales Type of convoy- Générales characteristics					
		Dénomination Designation	Longueur Length	Largeur Beam	Tirant déau Draught	Tonnage Tonnage		Longueur Length	Largeur Beam	Tirant déau Draught	Tonnage Tonnage	
			m	m	m	t		m	m	m	t	m
D'INTERET REGIONAL OF REGIONAL IMPORTANCE	I	Péniche Barge	38.50	5.05	1.80-2.20	250-400						4.00
	II	Kast-Caminois Campine-Barge	50-55	6.60	2.50	4.00-650						4.00-5.00
	III	Gustav Koenings	67-80	8.20	2.50	650-1000						4.00-5.00
D'INTERET INTERNATIONAL OF INTERNATIONAL IMPORTANCE	IV	Johan Welker	80-85	9.50	2.50	1000-1500	▬	85	9.50	2.50-2.80	1250-1450	5.25/or 7.00
	Va	Grand bateaux Rhenands/Large Rhine Vessels	95-110	11.40	2.50-2.80	1500-3000	▬	95-110	11.40	2.50-4.50	1600-3000	5.25/or 7.00/or 9.10
	Vb						▬	172-185	11.40	2.50-4.50	3200-6000	
	VIa						▬	95-110	22.80	2.50-4.50	3200-6000	7.10/or 9.10
	VIb		140	15.00	3.90		▬	185-195	22.80	2.50-4.50	6400-12000	7.10/or 9.10
	VIc						▬ ▬	270-280 193-200	22.80 33.00-34.20	2.50-4.50 2.50-4.50	9600-18000	9.10
	VII						▬	285 195	33.00 34.20	2.50-4.50	14500-27000	9.10

Source: AVV Transport Research Center, Ministry of Transport, Public Works, and Water Management

According to general used definitions, small vessels are vessels with a tonnage less than 1.000 tonne. This means that waterways for small vessels comprise waterway class I, II and III. According to the CEMT-classification these are so called waterways of regional importance. Based on the normative vessel dimensions of different waterway classes Table 3.3 gives an overview of the container capacity of vessels for different waterway classes. It should be noted that in container transport the minimum height under bridges is of special importance. It determines the number of layers that can be transported. In general small waterways suffer more from height restrictions.

Table 3.3 Relation between waterway class and container capacity of vessels

Waterway class - type of vessel	Container capacity (in TEU) length x width x height
II / III	6 x 2 x 2 = 24
Neokemp	8 x 2 x 2 = 32
IV	10 x 3 x 3 = 90
V	13 x 4 x 4 = 208
VI	17 x 5 x 4 = 340
Jowi/Amistade	17 x 6 x 4 = 398

Table 3.4 gives an overview of the share of different waterway classes for the Netherlands, Germany, Belgium and France. About 50% of all waterways in these countries consist of small waterways. In France the share of small waterways is even nearly 75%. These figures

demonstrate the importance of small waterways in strategies to expand the role of barge transport.

Table 3.4 Length of waterway network by CEMT waterway classification (1999)

CEMT Classification	Netherlands		Germany		Belgium		France	
	Km	%	Km	%	Km	%	Km	%
I	1156	23	707	11	348	23	1896	22
II	1251	25	247	4	248	16	4175	49
III	212	4	659	10	-	-	414	5
IV	636	13	1499	24	520	34	86	1
V	1095	22	2173	34	142	9	296	3
VI	665	13	1106	17	282	17	1606	19
Total	**5015**	**100**	**6391**	**100**	**1540**	**100**	**8473**	**100**

Source: AVV Transport Research Center, Ministry of Transport, Public Works, and Water Management

3.3 Erosion of the market position of the small vessel

Since two decades the market position of the small vessel has been gradually eroded due to internal and external developments affecting the barge sector.

Spectacular increase in scale of operations

Motivated by economic triggers (reducing operational costs, improving competitiveness with other modes , acquiring new transport flows), and supported by legislation, there has been and there still is a continuous drive to increase the scale of operation. This trend has been accelerated by the spectacular growth of container barge transport.

Figure 3.1 very well illustrates the general increase in scale of operations. During the last fifteen years the number of vessels in the Dutch fleet decreased by almost 25%, while the fleet capacity hardly changed. The number of small vessels (less than 1000 tonne) decreased by nearly 50%.

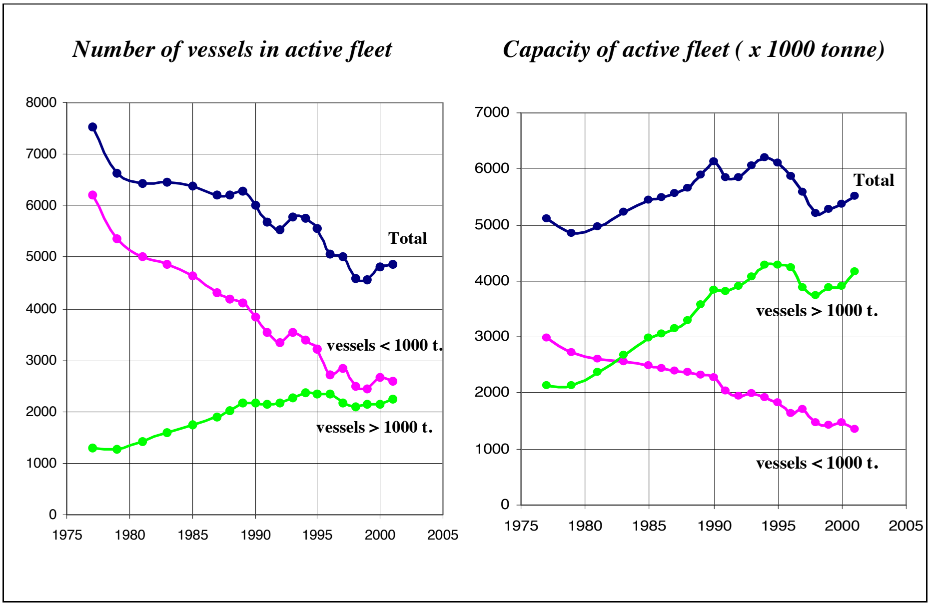
EU scrapping policy ('old-for-new' regulation)

In 1990 a European scrapping policy was implemented to reduce the structural overcapacity in the barge sector and to encourage renewal of the fleet. This policy was extended with a so called 'old-for-new' regulation. Due to these policies relative many small vessels have been withdrawn from the market, which also reinforced the trend of increased scale of operation.

Overdue maintenance of waterways

In many countries, the Netherlands in particular, for many years maintenance of waterways has been highly neglected, because of limited budgets and high costs of improving waterways. Large waterways have been prioritized in investment and maintenance programs. Substantial improvements of small waterways failed to materialize.

Figure 3.1 Number and capacity of vessels in the Netherlands (active fleet)



Source: Centraal Bureau voor de Statistiek (Central Office for Statistics in the Netherlands)

Efficiency improvements of road transport

Road transport has achieved considerable improvements in transport efficiency (improvements of utilization rates and reduction of empty hauls). As a result it has become a stronger competitor for, in particular, small vessels. In addition, a shift in commodity structure and changes in logistic requirements have also been more advantageous for road transport. This situation not only caused loss of market share in existing market segments, but also hindered entrance of new ones. Illustrative is that until recently it was assumed that small vessels could not compete with trucks in container transport.

3.4 The present role of small waterways in terms of container transport volumes

In a time span of thirty years container barge transport has developed into a very professional and mature transport industry. Its successful development is very well illustrated by the enormous growth of transport volumes, in particular since the mid eighties, showing annual growth figures of 10%. Total annual volume transported by barge in North-West Europe is estimated now at about 3 million TEU.

From a geographical perspective it is clear that container barge transport is still a very port-based system with a major role of Rotterdam and Antwerp and the Rhine river. In 2002, Antwerp handled a barge transport volume of around 1.7 million TEU incoming and outgoing. About 50% of this (850,000 TEU) was generated on the Antwerp-Rotterdam route. In Rotterdam the total number of barge handlings approached 2 million TEU in 2002

(Notteboom & Konings, 2003). In terms of modal split barge has a share in inland container transport of 31% for Antwerp and 43% for Rotterdam – Maasvlakte. In view of these volumes the role of barge transport in other European ports such as Hamburg and Le Havre (< 100,000 TEU) is still very modest.

Accommodating a transport volume of more than 1.2 million TEU the Rhine river is the most important barge route for Rotterdam and Antwerp. So roughly 40% of all container barge traffic in Europe is Rhine river traffic, about 30% is Rotterdam – Antwerp traffic and another 30% is barge traffic which consists of more dispersed traffic, i.e. mainly port-related traffic to different inland destinations. The latter has been the most recent growth market and has been accompanied and facilitated by the emergence of many new barge terminals increasing the scope of container barge transport.

In the development of barge transport on the Rhine and Rotterdam – Antwerp route the presence of large waterways (class VI) has played a major role, but due to new services to new inland destinations also smaller waterways have demonstrated their potential. However, as Figure 3.2 indicates the role of small waterways is still modest.

3.5 Endeavours to develop container barge transport on small waterways

In order to develop container barge transport on small waterways some opportunities have been elaborated in the past with different results.

3.5.1 Low-cost inland terminals

Transhipment (and also pre- and end-haulage) costs have a substantial share in the total costs of intermodal container barge transport. Considering the cost structure of barge transport this is even more the case for barge transport on small waterways. Moreover conventional barge terminals require substantial transport volumes for a cost-effective exploitation.

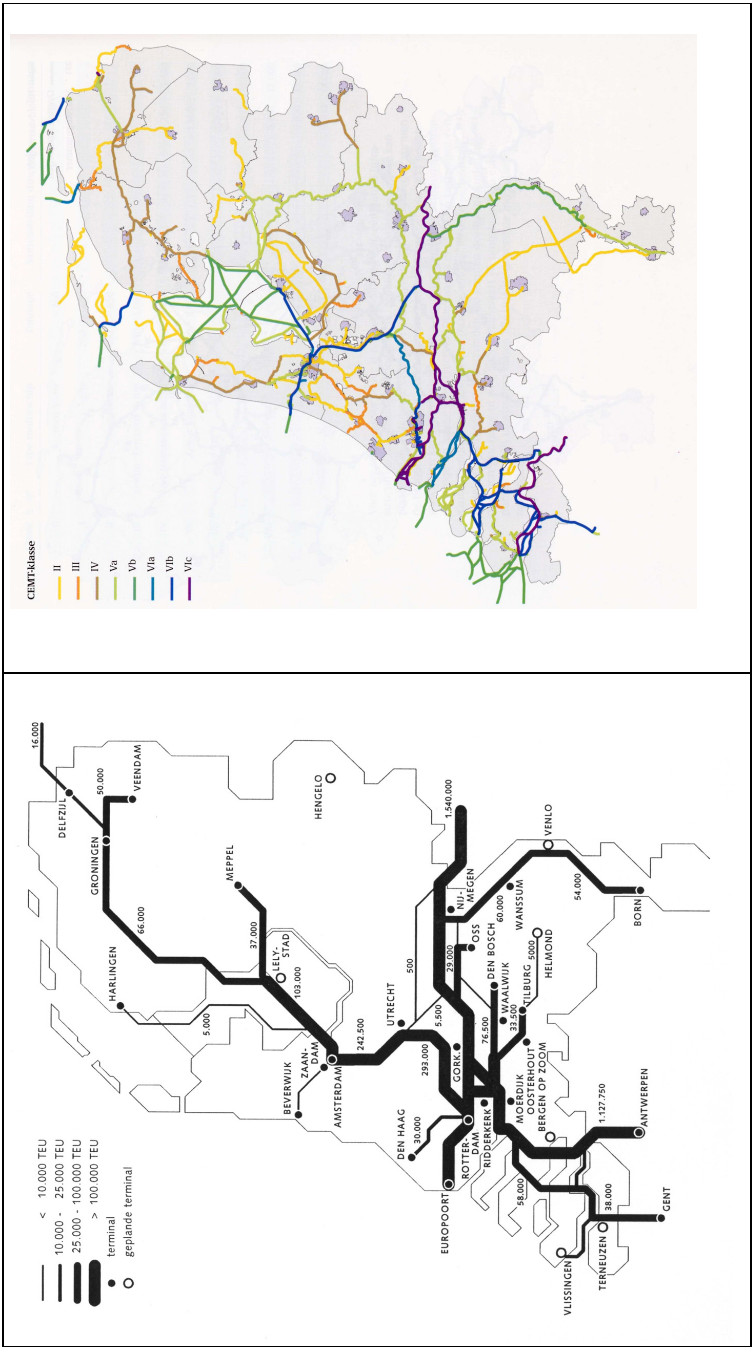
In 1998 a study was conducted into a barge terminal design which aimed to improve the cost performance of intermodal barge transport for small (continental) transport flows and so would contribute to a better use of small waterways. This design was focussed on low-cost and small-scaled operations. Characteristic features of this terminal included:

- Unmanned terminal (self-service terminal): the shipping crew performs crane operations and terminal transport (to reduce exploitation costs);
- Light-weight crane;
- Cheap quay facilities / shore protection;
- Stacking on wheels: decoupling of terminal processes and truck visits;
- Scalable for larger transport volumes (introduction of terminal staff, re-organisation of terminal processes).

Total investment costs of this terminal are estimated at 50% of the costs of a conventional barge terminal, which provides favourable conditions to develop competitive barge transport services.

The feasibility study of this terminal concept was promising (Van den Wall Bake, 1998). Far advanced plans for a pilot existed, but because co-finance of the government was cancelled market actors withdrawed.

Figure 3.2 Container barge transport flows in relation to waterway infrastructure



3.5.2 Adapted vessels

Self-unloading vessels

To achieve a high level of flexibility in possible locations for (un-)loading container vessels, independent of transport volumes, self-unloading vessels would be pre-eminently suitable for rather small-scaled and dispersed container transport. In the past several studies into self-unloading vessels have been conducted, in which different technical designs have been elaborated (Savenije, 1997; Willems; 1998). Such vessels are technically feasible, but the economic feasibility is questionable. The crane on board consumes space at the cost of, already limited, loading capacity.

Neokemp

To overcome the unfavourable characteristics of the existing fleet of small (waterway class III) vessels to transport containers, a new type of vessel within this class was introduced in 2000 by the Dutch company Neo Logistics Services. In this type of vessel, called Neokemp, the following innovative characteristics have been implemented:

- The cockpit is located in front of the vessel, which reduces the required height of the cockpit;
- Optimal use of space to maximize loading capacity. At dimensions of 63 by 7 metres its capacity is 32 TEU (two layers);
- A large motor power provides the vessel a relative high speed.
- Two propulsion propellers and a bow thruster are installed, which make the vessel very manoeuvrable.

This design has shown its effectiveness and has given a new dimension to barge container transport. However, the present role of the Neokemp in the container barge transport market should not be overestimated. The total fleet of Neokemps now consists of nine vessels. The Neokemps are not exclusively being used for transport on small waterways, but generally they are operated in rather short-distance services.

Push barge concepts

There is a wide range in the dimensions of existing barges. In addition, the investment costs of barges are relatively low and the exploitation risks are limited. This provides interesting opportunities to use barges having dimensions perfectly matched with the dimension of waterways. So barges are very suited to offer tailor-made solutions, which can be useful to develop transport on very specific waterway routes.

Examples are found in France (Lille) and the Netherlands (province of Brabant). Initiated by the port of Lille a special container barge has been implemented for transport services in Northern France. This push barge measures 95 by 9,60 metres and including the push boat the length of this transport unit is 110 metres. Transport capacity of this new barge is 78 TEU (with two layers containers), which is an increase of 40% compared to the equipment that could be used in this region so far.

In the Netherlands experiments with using barges on the canals of Brabant have been carried out to test and demonstrate possible increases of scale on these small waterways.

3.6 Alternative strategies: revision of network operations

Instead of offering direct barge services to destinations along small waterways, it may be interesting to change such a service into a trunk-feeder service. Such a service assumes that the feeder service is implemented at the small waterway and connects to the trunk service which is offered at a large(r) waterway. This network design offers potential cost advantages on both the trunk and feeder part of the route through a better utilisation of vessels.

In general the productivity of a vessel depends on the distance about which services are offered. At increasing distances the vessel productivity decreases, but this affects the performance of a small vessel in particular. Although small vessels have shorter roundtrip times than large ones, this advantage is at increasing distances increasingly cancelled out by scale advantages of large vessels. Therefore small vessels will be most economically implemented on rather short distances. This supports the presumption of a useful role of a small vessel in the feeder part, i.e. the short distance section, of a trunk-feeder service.

Possible cost advantages on the trunk route can be achieved by additional transport volumes generated at the feeder route, which enables economies of scale[15] that can be made possible because of good waterway conditions on the trunk section of the barge service. Evidently, these cost advantages not only accrue to containers with destinations along the trunk route, but also to containers destined for terminals along the feeder route.

Due to an additional transhipment from the trunk to feeder route some of these costs savings will be absorbed, but the net benefit might be an improvement of the total cost performance of barge services.

3.6.1 Numerical example

The potential benefit of substituting a direct service into a trunk-feeder service might be illustrated by an example. Let us assume a waterway route between A and C of 300 km length, which covers a section of 250 km of class V waterways and a section of 50 km which can only accommodate vessels of class II/III waterways. The 50-km section is a branch of the larger class V waterway. Both waterways come together at point B, where a terminal is located.[16] At the small waterway, vessels can load containers in only two layers. A service of at least three times a week should be offered between point A and C to comply with the needs of clients, i.e. shippers. Vessels can be hired on the spot on a per-journey basis because of abundant vessel capacity in the market. As a result vessel costs are determined per journey. Vessel costs are deduced from an average annual performance. The costs include the following cost categories:

- Personnel costs;
- Material costs: capital costs (depreciation, interest), insurance, 50% of repair and maintenance costs (50% is assumed variable costs), miscellaneous (certificates, communication etc.);
- Fuel costs;
- Repair and maintenance costs (variable part).

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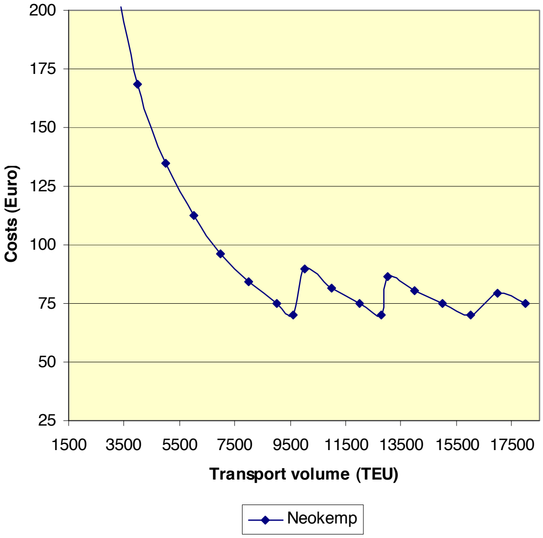
[15] Instead of increasing the size of operation the additional transport volumes originating from the feeder route could also be used to increase the frequency of services on the trunk route.

[16] The presence of a terminal exactly at the crossroads of waterways is not a must. A terminal located along the large waterway at some distance form the branch could still facilitate trunk-feeder services.

Considering the restrictions regarding vessel size on the last 50 km of the journey to reach point C, it can be assumed that a Neokemp is used to offer direct services between A and C at a frequency of three times a week. Figure 3.3 shows the indicative costs of this service for varying annual transport volumes. Costs per load unit (TEU) decrease continuously at increasing transport volumes until the maximum capacity of a Neokemp with a frequency of three times a week is reached. Larger annual transport volumes require additional sailings, i.e. an increase in the service frequency. As Figure 3.3 shows, this increase influences the cost level.

Figure 3.3 Transport costs of direct services (costs per TEU)



In contrast, a trunk-feeder service can be considered in which a Rhine vessel operates between A and B and the Neokemp operates only between B and C. The frequency should remain three times a week. It is assumed that containers cannot be directly transhipped from the Neokemp to the Rhine vessel, but must be temporarily stacked at the quay, and that the average loading degree of the Rhine vessel at the route between A and B is 80%. This loading degree reflects the transport volume generated by B and C together. In Figure 3.4 the indicative costs of both the direct and trunk-feeder service are represented. The costs per load unit (TEU) are lower in a trunk-feeder service, independent of transport volumes. However, the cost advantages are much larger in case of small transport volumes.

The benefits of a trunk-feeder service will be greater if transhipment costs can be reduced by board-to-board transhipment, which saves one handling. In addition, the loading degree on the route A and B can be higher if B generates a large transport volume itself and if it can benefit from the additional volumes generated at C. Figure 3.5 contrasts the costs between a direct service and a trunk-feeder service under these more favourable conditions.

Figure 3.4 Transport costs of direct and trunk-feeder services (costs per TEU)

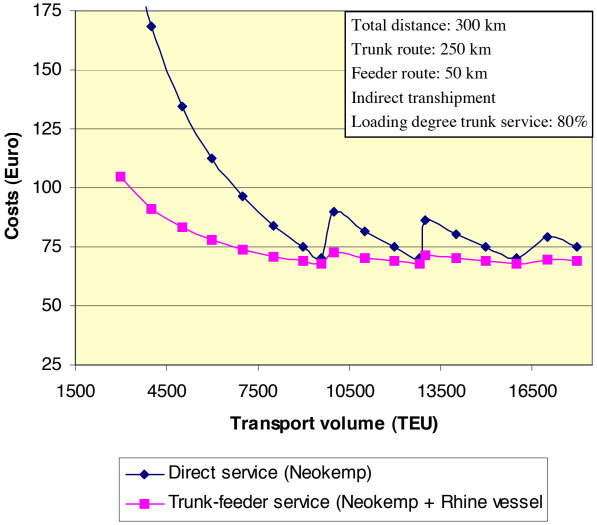
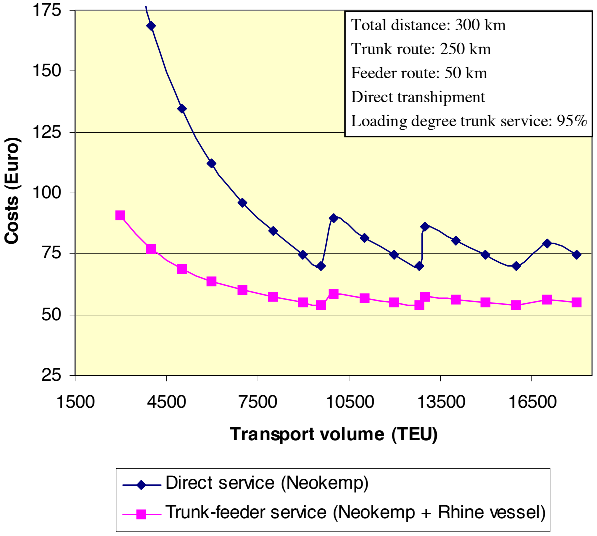
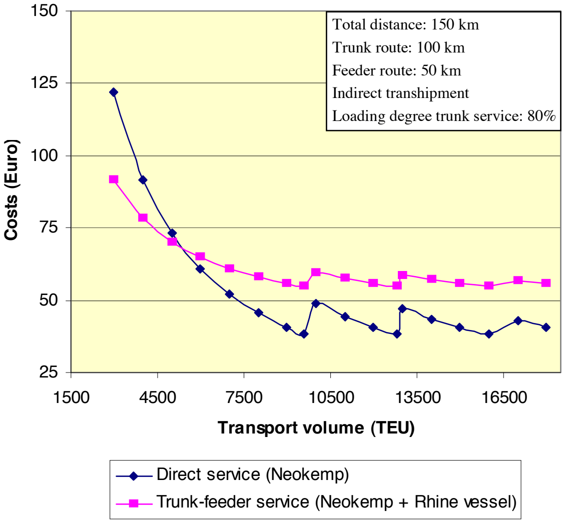


Figure 3.5 Transport costs of direct and trunk-feeder services (costs per TEU)



The potential benefits of a trunk-feeder service also depend on the configuration of the trunk-feeder network. Figure 3.6 shows a cost comparison between a direct and a trunk-feeder service, where the trunk route is 100 km and the feeder route is 50 km. In this situation, the cost advantages on the trunk route are insufficient to compensate for the additional handling (transhipment) costs.

Figure 3.6 Transport costs of direct and trunk-feeder services (costs per TEU)



3.6.2 Practical experiments: Rhein-Westfalen Shuttle

A good example of a situation in which the trunk-feeder model is being tested is the Rhine Westfalen Shuttle. It consists of a feeder service connecting Dortmund with Duisburg/Krefeld (distance: 47 km), which offers direct access to trunk (container shuttle) services from Duisburg/Krefeld to the seaports of Antwerp and Rotterdam (distance: 240 km).

Although market studies indicate at considerable container transport volumes between the region of Dortmund and the Benelux seaports, barge transport has never been seriously developed so far. Dortmund is located along the Rhine-Herne canal which can accommodate class V vessels, but vessels only can load two layers because of low bridges. So the loading capacity is restricted to 50% of its maximum capacity.

In view of potential transport volumes, barge operator CCS and Duisburg Container Terminalgesellschaft (DeCeTe) started this new container service on the Rhine-Herne canal last year. In this feeder service a vessel having a maximum capacity of 108 TEU (effectively 54 TEU) has been implemented, that offers two sailings per week to Duisburg and one to Krefeld. At these terminals containers are transferred to barge shuttle services to the port of Rotterdam and Antwerp, possibly by board-to-board transhipment, otherwise through temporary quay stacking.

The Rhine-Westfalen shuttle has been initiated as a 3-year pilot and is financially supported by the regional government of Noordrijn Westfalen in the framework of a modal shift policy.
So far the loading degree of the vessel varied on average between 45% and 65% (24 – 35 TEU per trip), but according to CCS/DeCeTe it should become around 80% to be profitable. During its first year of operation about 5,000 TEU were transported. Planned volumes for 2003 and 2004 are 10,000 and 15,000 TEU respectively.
In addition to the Rhine-Westfalen shuttle in Germany other examples exist of endeavours to develop barge transport on tributaries of the Rhine by implementation of trunk-feeder services, e.g. on the Neckar river.

3.7 Conclusions

In this paper we have addressed the challenge for the container barge sector to increase its market share by increasing its geographical scope. Since many years container barge transport has been a strong growing business, but due to a strong focus on increasing the scale of operation container barge transport has been mainly developed on large and middle-sized waterways. The opportunities to develop container barge transport on small waterways have been highly overlooked and its development has also been discouraged by transport policies. Considering that about 50% of all waterways in The Netherlands, Belgium, France and Germany consist of small waterways this indicates on a potential large market to further increase its market share. For reasons of accessibility small vessels obviously have to play an important role in opening up these new geographical markets. This strategic role of small vessels is more and more recognised and has resulted in new vessel designs better adapted to current customer needs and to the dimensions of waterways. Some recent projects with revised small vessels might here act as an example and stimulus for wider implementation. However, in addition to this technical solution we have argued the opportunities for logistical solutions to develop and improve the competitiveness of container barge transport on small waterways, i.e. the revision of network operations.

We have shown that substituting a direct barge service into a trunk-feeder service can improve the cost-quality performance of barge services to destinations along small waterways. However, there are many factors, which influence the network performance. The network configuration, i.e. the length of the feeder route related to the length of the trunk route, is an important factor. However, in addition to available transport volumes, there are many other external conditions (e.g. sailing speed regulations, presence of locks, height restrictions under bridges, terminal performance) and operational decisions (e.g. type of vessels used, service frequency and schedule, possibility of board-to-board transhipment) that influence the performance. Therefore the evaluation of the commercial feasibility of a trunk-feeder service to open a small waterway requires a tailor-made approach.
So far the trunk-feeder service concept for container barge transport is still rare, and, if applied, it is not really used for small waterways. Considering the potential benefits it would be worthwhile to further elaborate this concept for small waterways.

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4 Hub-and-spoke networks in container-on-barge transport

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Abstract

Container-on-barge transport has developed very successfully in Europe during the last two decades, but this transport business has been primarily focused on maritime container flows and therefore developed as a typical hinterland transport system. This paper postulates that to increase the market share of container-on-barge transport, and in particular to open up new geographical markets, would require new types of transport services in addition to the existing line and point-to-point barge services. The central question this paper deals with is whether hub-and-spoke services could be a fruitful tool to improve the performance of container-on-barge transport and so to gain market share. The typical cost, service and geographical characteristics of hub-and-spoke networks are discussed and illustrated with examples from the airline industry that has a rich history in hub-and-spoke research and applications. These general features of hub-and-spoke networks are used as a framework to explore the feasibility of hub-and-spoke networks in container-on-barge transport. The conditions and implications of operating these networks in barge transport are discussed. The discussion indicates that a hub-and-spoke network can result in efficient barge services, because it can make a vessel most productive through optimized sailing schedules and more efficient use of vessel capacity in case of differences in waterway dimensions. A major precondition however is a cheap, fast and reliable exchange of containers in the hub terminal.

4.1 Introduction

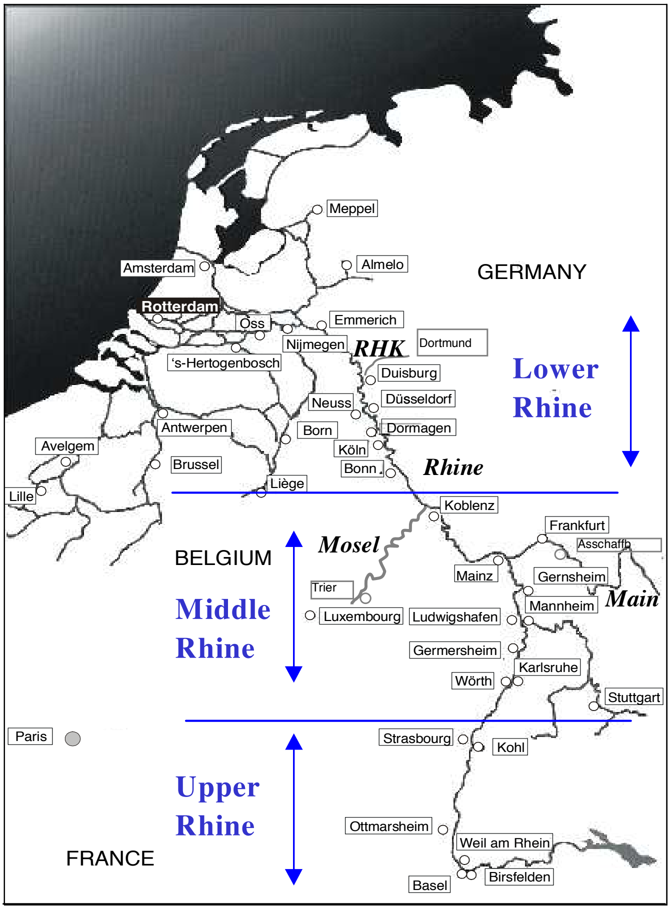
In a relatively short space of time barge transport has become a well-developed mode for transporting containers in Northwest Europe. Reliable and low cost barge services together with the provision of additional logistic services, such as the organization of drayage operations, have increased the interest in container-on-barge (COB) transport as an alternative for road transport (De Vries, 2000). Over the last decade COB transport has shown annual growth figures of 10 to 15%.

Geographically the development of COB transport has been dictated by the position and quality of inland waterways and the fact that this transport business is strongly related to deep-sea traffic. Container transport by barge is predominantly a transport mode to move maritime containers between the seaport and its hinterland. It has been mostly developed between the seaports of Rotterdam and Antwerp and the hinterland along the Rhine river. In 2004, total container traffic on the Rhine accounted for 1.8 million TEU. In this river corridor the market share of barge transport varies from 20% in the Lower Rhine river basin (from Emmerich to Bonn, Germany) to 35% in the Middle Rhine river basin (from Koblenz to Wörth, Germany) and around 70% in the Upper Rhine river basin (from Strasbourg, France, to Basel, Switzerland) (see also Figure 4.1). These market shares reflect the increasing competitiveness of barge transport to road transport on longer distances.

In addition to Rhine river transport, another major barge transport route emerged between Rotterdam and Antwerp. The development of COB transport here can be attributed to the main porting policies of deep-sea shipping lines. The container flows consist of feeder traffic between these mainports. In 2004 about 950,000 TEU were shipped between these ports.

For a long time these international traffic flows have set scene for the COB transport market, but the last decade new geographical markets are now also being opened up. In particular in the Netherlands barge container transport has developed spectacularly, demonstrating that barge transport can also compete with road transport on much shorter distances than previously assumed. Today in the Netherlands even more than 30 different services exist. In 2004 about 880,000 TEU were shipped by barges, predominantly between the port of Rotterdam and inland places. These domestic hinterland services are now also being developed in other countries. From 1998 the development of new inland terminals and barge services in Belgium increased from just two terminals to currently ten (Macharis and Verbeke, 2004). About 400,000 TEU were transhipped at the inland terminals in 2004. The transport volumes recorded in Germany (170,000 TEU) and France (120,000 TEU) are relatively modest, but hinterland container transport by barge is also on the way up in these countries. An overview of these major flows is presented in Figure 4.2.

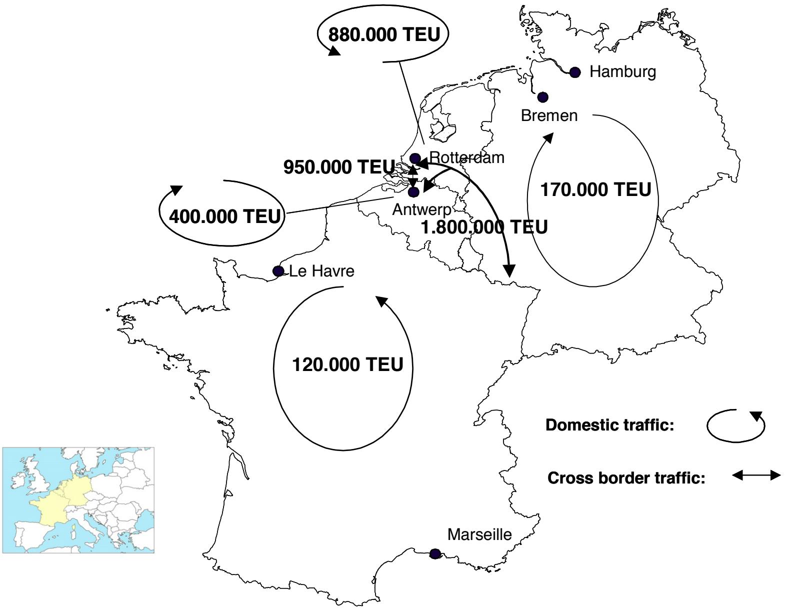
Figure 4.1 Partition of the Rhine river according to the turnaround time of vessels



Lower Rhine section: two roundtrips per week.
Middle Rhine section: one roundtrip per week.
Upper Rhine section: one roundtrip per two weeks.
RHK = Rhine-Herne canal.

Despite the flourishing development of COB transport there are reasons to assume that its performance can still be improved to increase its market share. The rising transport volumes create opportunities for improvements in efficiency, but at the same time they call for actions to maintain the high cost-quality level of barge transport. On the other hand, expanding into new geographical market areas requires the development of transport services that can compete with road and rail transport. It is here that network operations play a part.

Figure 4.2 Cross border and domestic container-on-barge traffic in Europe (2004)



The cost and quality of transport services are closely related to the network operations within which they run. Which networks are most favourable depend on the markets to be served. Obviously, markets with concentrated large transport flows will require different network operations than markets with dispersed small flows. Literature on transport networks shows that hub-and-spoke networks are pre-eminently suited to capture market areas with dispersed small flows. This finding is supported by successful experiences with hub-and-spoke networks in practice in different transport modes. However, in COB transport such network operations do not exist.

In this paper we explore the feasibility of hub-and-spoke networks as a fruitful concept to improve the cost-quality level of COB services and to enable an increase of market share of barge transport in existing and new geographical markets. In particular we discuss the conditions and implications of operating these networks in barge transport. The paper starts with some general notions on the role of service networks and goes on to discuss the specific features of hub-and-spoke networks as a framework to explore the feasibility of such networks in COB transport. Next the background and characteristics of existing networks in COB transport are explained. After that the conditions and implications of operating hub-and-spoke networks in this sector are discussed. Finally an outlook on the feasibility and implementation of these networks is given. All in all, this paper presents the arguments for and against hub-and-spoke networks in container-on-barge transport, but it does not test these thoughts empirically. As such it provides a basis for a next piece of analysis in which models can be developed to test the feasibility of actual network configurations.

4.2 The role of service networks in transport business

One of the major issues for every transport operator is how to use its scare resources to provide transport services. This is a delicate issue, because a transport operator is being confronted with a complicated interaction between demand (total revenues) and supply (total costs), which may strongly influence the decision process of allocating resources (De Wit and Van Gent, 1996). The fact that demand for transport services is irregularly spread in time and space has important implications for the utilization rate of transport services and hence for the type of networks in which transport services can be operated. Obviously a point-to-point service, which offers a direct connection between origin and destination of freight, fits to different type of transport flows then more complicated services such as trunk line with collection-distribution services and Hub-and-Spoke (H-S) services, which usually involve intermediate change of transport means.

A service network is actually the artifact or production model of transport services. It expresses *how* transport services are operated or scheduled and routed. The volume, spatial and time patterns of transport flows play a central role in the design of a service network. The basis for a service network design consists of bundling of transport flows.

Bundling can be defined as the common transport of freight belonging to different transport relations in common transport units (e.g. barge vessels) and/or load units (e.g. containers) during (common) parts of the routes (Kreutzberger, 2001). Basically the intention of bundling is to improve the cost-quality level of transport services, but the characteristics of transport flows (volume and spatial pattern) set the pre-conditions, and there will be a trade-off between the advantages and disadvantages of bundling.

First, bundling can contribute to higher loading degrees of transport units, which could result in an overall cost reduction. Second, bundling gives opportunities to increase the frequency. This reduces the time intervals between two sequential transports and so the total transit time can be shorter. This results into lower costs of goods in rolling stock to shippers and potential savings in equipment costs to transport operators due to a shorter turnaround time of transport units. Third, if many relations with small freight flows can be bundled a large number of destinations can be served, which would be infeasible with only direct (point-to-point) services. This is in particular a strong argument for bundling in intermodal transport, because point-to-point services require relatively large transport flows in intermodal transport.

On the other hand, bundling has a number of disadvantages. First, there is a need for extra transhipment, which makes a transport service possibly more expensive, slower and less reliable. Second, bundling causes detours, compared to a direct transport route. Third, the longer routes may require more transport units to be operated in the network.

Dependent on the characteristics of the transport volumes and these specific (dis)advantages different bundling patterns may be useful. Many possibilities to bundle freight exist, but these can be reduced to four basic bundling or network models:

- Point-to-point network (direct connection, bundling for one transport relation);
- Line network;
- Trunk line with collection/distribution (or feeder) network;
- Hub-and-spoke network.

These theoretical bundling models are a useful starting point to investigate the merits of existing bundling concepts for COB transport and the feasibility of new bundling concepts, such as the hub-and-spoke network.

4.3 A closer look at the specific features of hub-and-spoke networks

Perhaps one of the most fascinating features of H-S networks is that it is an ultimate form of bundling, which generates a maximum bundling effect (Klaus, 1985). In the H-S network origins and destinations are connected with star-shaped transport links (spokes) via one or more centrally located points, i.e. terminals (hubs). Hence freight belonging to different transport relations is in principle always transported jointly.

The major driving force for a H-S network is an economic one, although the potential benefits do not only relate to costs, but also to service characteristics as well as typical geographical features. These elements are highly interrelated.

We will now briefly discuss these cost, service and geographical characteristics of H-S networks and illustrate them with examples from the airline industry that has a rich history in H-S network research and applications. Later on we will look at their meaning for COB transport.

Multiplicator effect: increasing the supply of services

One of the great advantages of a H-S network is that less number of direct links are necessary to connect all nodes, i.e. origins and destinations, in a network. Conversely with a given number of spoke links more origins and destinations can be connected than the same number of direct links can do. The increase of the number of links between origins and destinations is multiplicative to the increase of the number of spokes. If n spokes exist, n direct connections to the hub can be offered, but because of a hub transfer also $n(n-1)/2$ indirect connections are possible. Hence in total $n(n+1)/2$ connections can be offered. This means for instance that 4 links can only connect 4 origin and destination pairs in a point-to-point network, while in a H-S network it could connect 10, i.e. 4 direct links to the hub and 6 indirect links via the hub (see Figure 4.3).

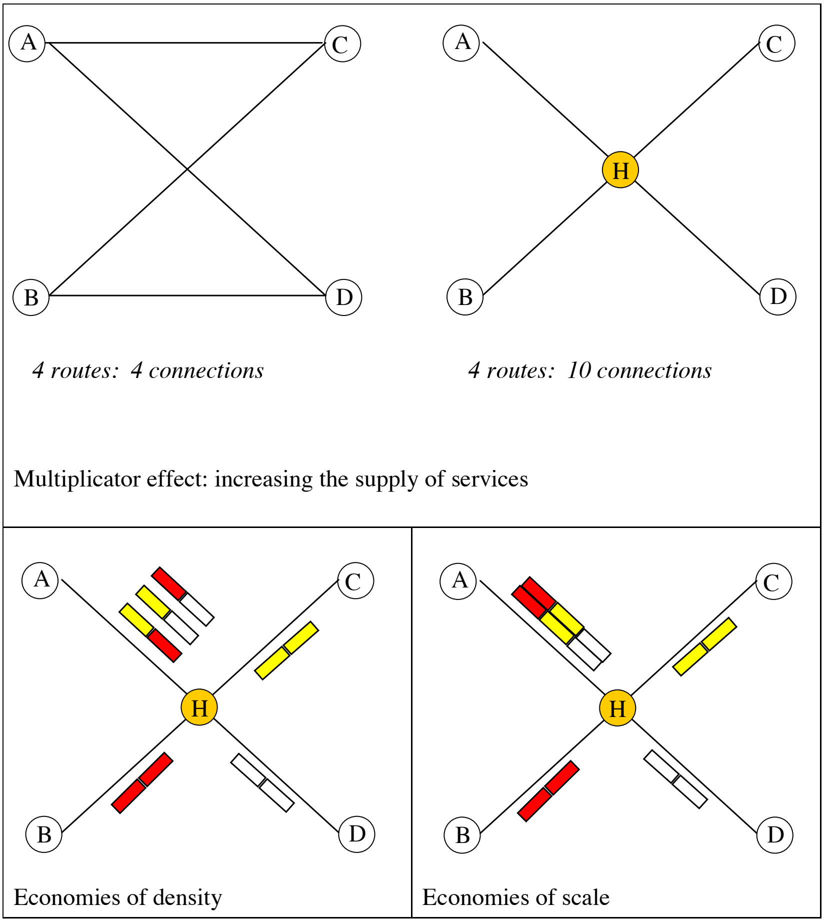
Economies of density

Freight with different destinations is consolidated in spoke links. This enables a better utilization rate of transport means: the loading capacity of transport means can be better utilized or the number of roundtrips of transport means can be increased. The latter indirectly results in cost reductions, but also enables a better quality of services through an increase of frequency (see Figure 4.3). These cost advantages, which occur because of higher frequencies, are in literature often defined as economies of density. The existence of economies of traffic density in the airline industry is extensively discussed in the work of Tretheway and Oum (1992).

Economies of scale

In addition to increasing frequencies to accommodate consolidated transport flows on the spokes also larger transport means can be used. The average costs will reduce if larger transport means with a larger loading capacity are operated and these effects are known as economies of scale (De Wit and Van Gent, 1996) (see Figure 4.3). These advantages have both a technical and operational background. Economies of scale have beneficial effects on both the fixed and variable costs of operations. Empirical evidence for these scale advantages that accrue from operating H-S networks is mainly found in the airline industry (Morrison and Winston, 1986; McShan and Windle, 1989; Antoniou, 1991). The size of aircrafts in flights to a hub generally increase, but particularly in networks with more than one hub the inter-hub flights are a major source of scale effects, because of aggregated transport volumes in such connections. The economies of scale however, do not only appear in the transport operation, but can also be reaped in centralized ground support and maintenance of an airline's equipment at the hub (O'Kelly, 1998).

Figure 4.3 Features of hub-and-spoke networks



Economies of scope

Economies of scope arise if the costs of a joint production of services are lower than the separate production of these services. In general it is related to the fact that transport companies act as multi-product firms, where resources can actually be used to supply different kind of transport services. For instance, an airplane can transport passengers and cargo together. In this case passenger and freight transport services are the result of a joint production, in which the average costs of transporting passengers and cargo together can be lower than transporting them separately. There are many causes for economies of scope (see e.g. Korver *et al.*, 1992), but their occurrence in transport networks is one of particular interest.

Consolidation of transport flows on the spokes implies that passengers or freight with different destinations are jointly transported. A commonly operated network expresses the joint production characteristics. The economies of scope do not only consist of commonly used transport resources, such as transport units and staff, but also include common use of hub facilities (Mayer, 2001).

Economies of scope differ from economies of density, because it does not address the cost issue of intensifying an existing transport network, but rather the cost effects of increasing this existing network. Expansion of a H-S network with one spoke results in decreasing average costs, but of course this additional spoke can also bring on economies of scale and density.

Robustness to demand fluctuations

The joint character of providing services on a H-S network implies a dependency between all the links in the network. The advantage is that services from spoke terminal A to spoke terminal B are less dependent on fluctuations in demand on this origin-destination pair of terminals. This means that even if demand drops the frequency of services linking A to B can usually still be maintained (see also Teuscher, 1993).

Higher frequency of services

In addition to cost reductions that might result from higher service frequencies (economies of density), higher service frequencies are acknowledged as an important quality feature of H-S networks. Higher service frequencies arise from the typical routing in a H-S network. Higher frequencies reduce the waiting time between a desired departure time and the available departure time and also increase the choice of possible departure times. Both aspects are part of the quality of services (Janic, 2000). For the airline industry evidence exists that this can strengthen the market position of a transport operator. For instance, Bailey *et al.* (1985) and Hanlon (1996) have shown that increasing the flight frequency on a specific link results in a more than proportional increase of the local demand for flying on this link. Butler and Huston (1990) indicate that due to these effects air transport could become more competitive to other modes of transport on shorter distances. Morrison and Winston (1986) state that the features of higher frequencies and more destinations in H-S networks have in particular attracted business travelers. Such customers show pre-eminently a rather time elastic instead of price elastic demand behavior. It is interesting to note that the flight frequencies and concentration of take-offs and landings can apparently compensate the time loss of transfers.

More efficient terminal operations

One of the implications of a H-S network is a changing role of the nodes or terminals in the network. This is even more profound for dedicated freight H-S networks, such as those operated by integrators, than the H-S networks operated by most airlines. For the nodes or terminals acting as a hub the transfer and sorting function becomes of vital importance. The construction of hub facilities will generally involve large investment costs and also significant exploitation costs, which must be recovered by a high utilization rate of these facilities, i.e. large transport volumes. Large-scale operations will enable economies of scale, but eventually these additional costs of transferring and sorting should be compensated somewhere else in the network, i.e. at the spoke links and terminals.

The location of the hub may be a major cost factor as well. As a hub is basically an exchange point the 'situational factors' of a hub location may become of less importance than the 'site factors' of the location (see Fleming and Hayuth (1994) and Boyce and Ullman (1980)). This means that for a hub acting as a pure exchange point a cheap land location (away from heavy congested areas) could be an ideal location. However, this 'freedom' in choosing a hub location is very much related to required levels of services, price and demand. For freight H-S networks this hub location decision will be less restrictive than for passenger H-S networks. In freight traffic the attraction of a service for a client is not a function of the routing of freight, while in passenger traffic the inconvenience of intermediate stops can not be ignored (O'Kelly, 1998).

Just like the operational advantages in hub transfer operations also operations in spoke terminals could become more efficient. Due to the specific routing the sorting of freight to different destinations becomes much simpler or even redundant.

Congestion and capricious capacity use at hubs

One of the consequences of routing transport flows through a hub is that it makes high demands to coordinate the arrival and departure times of inbound and outbound traffic. The time window for arrivals and departures should be relatively small to keep the time loss resulting from a transfer as small as possible, and so limiting the increase in total transit time. This means for instance in the airline business that many aircrafts have to land and take-off in a small time span, in which the infrastructural and personnel capacity at the hub becomes overloaded (Mayer, 2001). This endangers the reliability of services, and because of the interdependence of the connections, the total transit time of passengers or freight. This typical time pattern of inbound and outbound traffic also has a negative effect on the capacity use at hubs. The infrastructural and personnel capacity must be large enough to handle such peak demands, but on the other hand outside these peak periods capacity will be over dimensioned or even idle. This can be a major source of additional costs for operators running a H-S network (Wheeler, 1989), but it may also have consequences for other actors involved in H-S networks, for instance airport operators in the airline industry (Kanafani and Ghobrial, 1985).

Vulnerability to disruptions

An implication of the interdependence of connections in a H-S network is the vulnerability to disruptions. If a problem occurs on a particular spoke route (e.g. a serious delay), it may affect many services at other spoke routes and hence influences the performance of the total network. Of course, traffic congestion at hubs can be a cause for disruptions of services as well.

Detours: longer distances and larger transit times

The indirect connections via a hub result in longer transport distances and consequently in larger transit times. In addition, the required transfer in the hub also has a negative effect on the transit time. In general these effects will have stronger implications for transport of passenger than freight. Time sensitivity is quite different in the passenger and freight transport market. Nevertheless, there are numerous examples from the airline industry where also rather time sensitive goods are transported in a H-S network (e.g. DHL, Federal Express and Emery). In a freight transport system operators may direct flows along paths that are optimal for the system with the lowest costs for the entire network by indirect routes and bundling flows (O'Kelly and Bryan, 1998). In passenger transport the acceptance of the traveller plays a role. In the case of air passenger transport systems, the ability of operators to exploit the H-S network is tempered by the need to recognize the impact of the network design on costs as well as revenues (O'Kelly, 1998). However, the worldwide use of H-S networks in air transport is probably the best indicator that this disadvantage of detours can be offset by many advantages of this type of network design.

4.4 Present service networks in intermodal barge transport

Up to now COB transport has been primarily focused on maritime container flows and therefore developed as a typical hinterland transport business. As such, the development pattern of the barge network is strongly entwined with the development of the container seaport system (Notteboom and Konings, 2004). In addition, the characteristics of the different hinterland markets, as described in the introductory section, play a part in the type of transport services offered.

In the Rhine river traffic the commonly operated transport service is the line service. A vessel sails between the seaport and one of the three regions in the hinterland (i.e. the Lower, Middle or Upper Rhine river basin), where about 3 to 5 terminals are visited in the hinterland region. This geographical segmentation of operations along the Rhine river is related to efficient sailing schedules of vessels (see Figure 4.1). At the moment there is only one Rhine terminal that has a direct connection to the seaport, i.e. the DIT-terminal in Duisburg. In addition to these services some trunk line-feeder services exist to offer services along tributaries of the Rhine river. Containers are shipped in regular (trunk line) services to 'cross road' terminals where these containers are transhipped to a feeder service to arrive at their destination terminal. These kind of services are operated to Trier (along the Mosel river), Frankfurt and Asschaffenburg (along the Main river) and Dortmund (along the Rhine-Herne canal, RHK) (see Figure 4.1). It should be noticed, however, that all barge hinterland services include local collection distribution in the seaport, due to the existence of several deep-sea and barge terminals in the port (Konings, 2005).

In traffic by barge between Rotterdam and Antwerp the role of the shipping lines greatly influences the characteristics of the barge services. The batches of containers are very large which enables to have a limited number of terminal calls in the ports and to use large vessels. The barge services can be defined as point-to-point services that generally have limited local collection/distribution within the seaports.

In domestic hinterland transport almost all barge services are offered as a point-to-point service, i.e. a direct service between the inland terminal and seaport without intermediate stops. This has much to do with the transit time. The transit time should be kept small for these barge services on rather short distance (50 to 150 km), because of heavier competition with road transport. The fact that the exploitation of the barge service and the terminal are usually in one hand also explains a direct service.

4.5 Key aspects to consider in operating hub-and-spoke networks in container-on-barge transport

The bottom line of a hub-and-spoke network design involves a decision on *where* to place the hub (a location decision) and *how* to route the traffic that is to flow between the origins and destinations over the resulting network (O'Kelly, 1998).

The hub location is an important starting point, but the location decision also involves the question of how many hubs are needed. This choice has great effect on the complexity of the routing decisions. It is evident that in the one hub network the routing problem comes down to a decision whether all node-to-node flows will pass through the hub or not. In the multiple hub network additional choices come into play: should a node be connected to just one hub (the nearest by) or to several hubs and should the hubs be fully connected or not? (see also O'Kelly and Miller, 1994).

We use these considerations as a starting point to discuss the conditions and implications for operating H-S networks in COB transport and point out which other aspects should be considered.

4.5.1 Location of nodes

A hub-and-spoke network in COB transport would enable operations according to what O'Kelly (1998) defines as a delivery system. This means that in principle the barge operator decides where to place the hub and spoke terminals and has complete control over the rules for routing containers in the network, because the attraction of the service for the shipper would not be a function of the routing of the containers. In such a system the cost of the transport service would be mainly a function of the location of the hub and spoke terminals, but in practice several conditions should be considered.

Hub location

The location choice for the hub will be strongly determined by the position and quality of the inland waterways. The hub terminal should be preferably located at or nearby crossroads of good navigable waterways. This is a basic requirement to enable a star-shaped network configuration. Although the main function of the hub terminal is to transfer containers it seems most interesting to locate the hub in a place that has the attributes of *centrality* and *intermediacy*. The importance is that these attributes help to feed the network with cargo. A COB terminal that has substantial own traffic-generating power due to its size, function and location makes it a lot easier to set up new barge services into new directions. A well-developed linkage between a seaport and an inland terminal in hinterland traffic would give this inland terminal an asset to be a potential hub. This linkage would form a strong (starting) spoke in the network! In addition, the attractiveness of this potential hub location is increased if the location is *en route* in intermodal traffic flows. A location along a major hinterland corridor further helps the spoke development, but it would be useful if the hub location is also part of a corridor of continental intermodal cargo flows. If maritime and continental container flows can be bundled, it lowers the threshold to start a new spoke service.

Next to accessibility over water the opening up of the hub terminal by road is obviously important. This is a relevant issue for every intermodal terminal, but for a hub terminal, expected to feed the network with a base transport flow, in particular. Moreover, the closer shippers can be located near the terminal, the more attractive intermodal barge transport becomes. Around many existing COB terminals related business areas have been developed. The hub quality of a terminal, determined by the number of barge services to different directions, could reinforce the attractiveness of such terminal related locations for shipping companies.

Another condition to be considered is the available space at the terminal site or the possibility to expand the space. This holds for both the water and land surface. Quay and storage space is needed to enable exchange of containers.

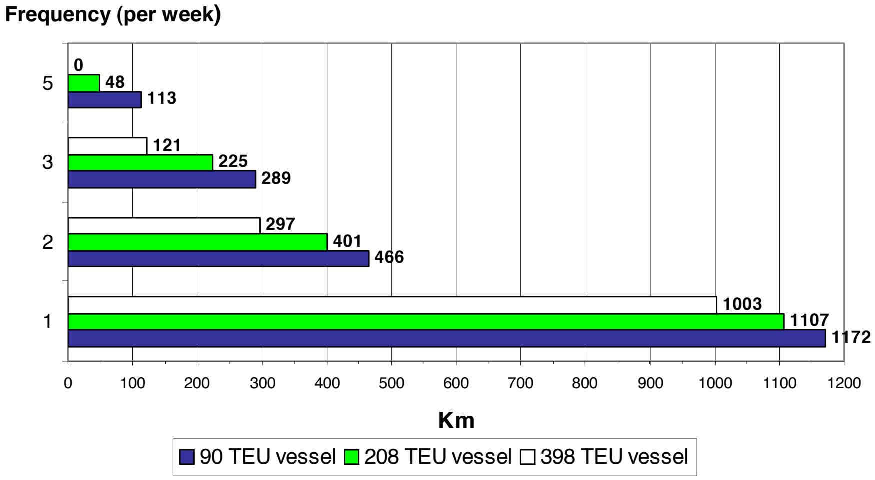
Spoke terminals: number and locations

In establishing a hub-and-spoke network not only the number of spoke lines matters, but also the relative location of spokes and the length of the spokes will influence the economic feasibility of the network. In a very dense network with many spokes the geographical coverage may be large, but the detours may also become large. So even if there is no alternative for a direct barge service, this is a critical condition for a slow mode like barge transport, because there is always the competition from road transport.

The length of the spokes is also a factor of obvious importance. First, an intermediate transhipment in the hub causes additional handling costs, which must be compensated by cost savings in sailing. However, sailing costs are relatively small compared to transhipment costs (see Konings, 2003). So, if the sailing distance increases, the share of transhipment costs in the total costs of barge services decreases and there is more room to gain cost reductions in sailing. Evidently, the barrier of relatively high transhipment costs would be even harder to overcome in a multiple hub network. The length of the spokes also plays a role in the competition with road transport: the smaller the spoke distances are, the stronger competition with road transport is.

Second, the length of the spoke connections will influence the productivity of the vessel. A relationship exists between the sailing distance and the service frequency that can be offered efficiently for a certain vessel size, which is based on the turnaround time of a vessel (see Figure 4.4). Differences in turnaround time between vessels having different sizes occur because of differences in total time consumption for loading and unloading vessels. For instance, a medium-sized vessel (capacity: 208 TEU) can make 3 roundtrips per week on a distance between 48 km and 225 km. On distances smaller than 48 km 5 roundtrips are possible and on distances longer than 225 km only 2 roundtrips can be made. In addition to time consumption at terminals the turnaround time is determined by conditions related to waterway characteristics e.g. sailing speed regulations and presence of locks. The distance classes have an impact on costs, as shown in Figure 4.5 for a small-sized (90 TEU) vessel. The larger the distance, the higher the costs are, but there are some leaps in cost levels with are related to the distance classes. As shown in Figure 4.5 costs are also related to the utilization rate of the vessel or the transport volume. Not only transport volume but the waterway characteristics as well condition the type of vessel that can be used, e.g. by draft limitations. In other words, the type of vessel can be tuned on one hand to the distance to be covered to gain maximum economies of density and on the other hand to the characteristics of the waterways to gain maximum economies of scale. If a vessel is only operated in one spoke link, it is possible to tune the vessel size optimal to the dimensions of that specific waterway, given that there is potential demand for these barge services. It is here where the traffic-generation of the spoke terminals comes into play.

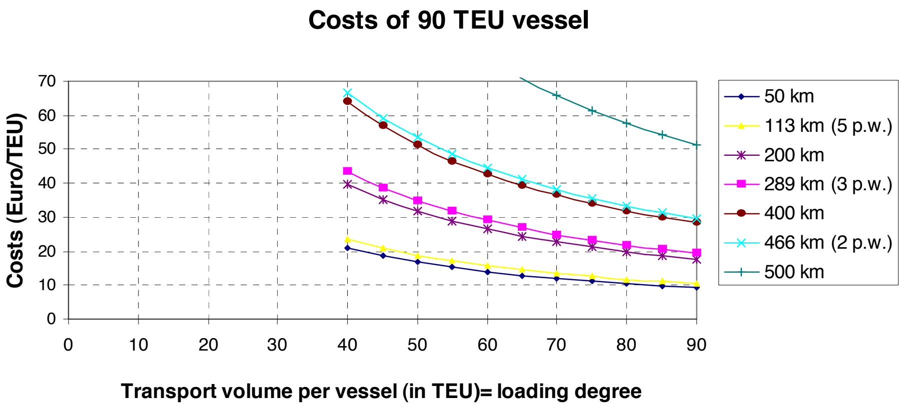
Figure 4.4 The relation between distance and frequency in barge services



4.5.2 Routing of traffic

As regards the routing of traffic through the network the situation in barge transport is quite different from other modes and air transport in particular. The network of inland waterways is a rather sparse network enabling less freedom to route traffic. In many situations the shortest path would be the common route, provided that, due to differences in navigability, this route is physically possible. To some extent a relatively sparse network might be considered as an advantage to implement a hub-and-spoke network, because a lot of traffic would more or less naturally flow through the hub.

Figure 4.5 The relation between costs and distance in barge services



4.5.3 Hub operations: transhipment

In the hub terminal an efficient exchange of containers between the different spoke services is needed. However, transhipment in barge transport is faced with some constraints that can endanger a fast and cheap exchange of containers.

Loading/unloading times of barges are relatively long

The main explanation for this is the large capacity of vessels, compared to for instance the capacity of trains. It takes much time to unload and load a vessel completely, about 6 to 8 hours for the most popular type of vessel in Europe, which has a capacity of 208 TEU. Of course, the time consumption will depend on the number of units to be exchanged, the available crane capacity and possible waiting times. The time consumption of exchanging containers between vessels may have a negative effect on the total transit time within the transport chain.

The difficulties of simultaneous exchanges

The exchange process requires vertical container handling operations by cranes. Direct exchange of containers between vessels is difficult to achieve, unless appropriate cranes are available and time schedules of vessels are tuned. If these conditions can not be met, temporary quay stacking and additional handlings are needed. This will increase the transit time and costs within the transport chain. It is conceivable that containers can be regrouped horizontally through the exchange of push barges, making the exchange process easier. However, this assumes that containers can only be regrouped batch wise in rather large batches, which make the hub-and-spoke system less flexible.

The importance of the loading/unloading order

Much more than for trains, the sequence of loading/unloading and the positioning of containers is critical and complex for vessels. Loading/unloading operations have to take into account vessel stability and the containers' position aboard in relation to its destination to avoid digging up containers, which results in additional handlings. Although excellent logistical planning may reduce this problem to some extent, this issue remains a huge challenge when applying complex bundling models in barge transport.

Whether these circumstances, and the time and money costs involved, are a real barrier depends on the specific networks considered: costs savings on the network level (for instance by economies of scale) may overcompensate the additional costs resulting from exchanging containers between barges.

Practical experiences show that barge networks with an intermediate transhipment can have a rationale. For example, CCS, a German-based barge operator, operates such networks to serve terminals along the tributaries of the Rhine river. These trunk line – feeder services are a cost-efficient alternative for direct services. Since exchange of containers is only between two vessels, this is not a very complex process. Nevertheless, the containers are usually not transshipped board-to-board, but are temporary stacked at the quay.

4.6 Conclusions

The spatial and functional development of COB transport networks is strongly determined by geographical and operational conditions. The inland waterway network basically has a treelike structure with little lateral connections between the different branches. As a result the estuaries of the rivers are a natural place to feed the network with transport volumes, and since COB transport has developed as a transport system to ship maritime containers to the hinterland of seaports the development of barge networks has predominantly consisted of line and point-to-point services between the seaport and its hinterland. In addition, there is a large difference in the navigability of the waterways due to variations in draft limitations and other physical conditions (e.g. existence of locks). This explains why some (trunk line) hinterland routes could be developed very well, while other routes (e.g. along small waterways) have not been (extensively) developed yet. Moreover, inherent characteristics of the barge transport system also have favoured the more simple networks that do not need intermediate exchange or transhipment of containers within the barge transport system. Efficient and fast transhipment between barges seems only possible under very restrictive conditions.

In view of the role of COB transport as a typical hinterland transport system and ever increasing maritime container flows, new network developments take place. In particularly the trunk line feeder service is increasingly being implemented. The trunk line feeder service however is still used in the market for hinterland transport. This paper postulates that a next step in network development could be the introduction of hub-and-spoke networks as a mode to capture new geographical markets, the market for continental cargo in particular. The hub-and-spoke network is a type of network that is pre-eminently suitable to enhance the geographical coverage of transport services, because it is a 'multi-directed' (star-shaped) network. Moreover, owing to its typical features the H-S network is also very suited to implement new services between origin-destination pairs for which the transport flow is too small to run a direct (point-to-point) barge service. Both these characteristics of H-S networks are therefore highly supportive to enable market expansion.

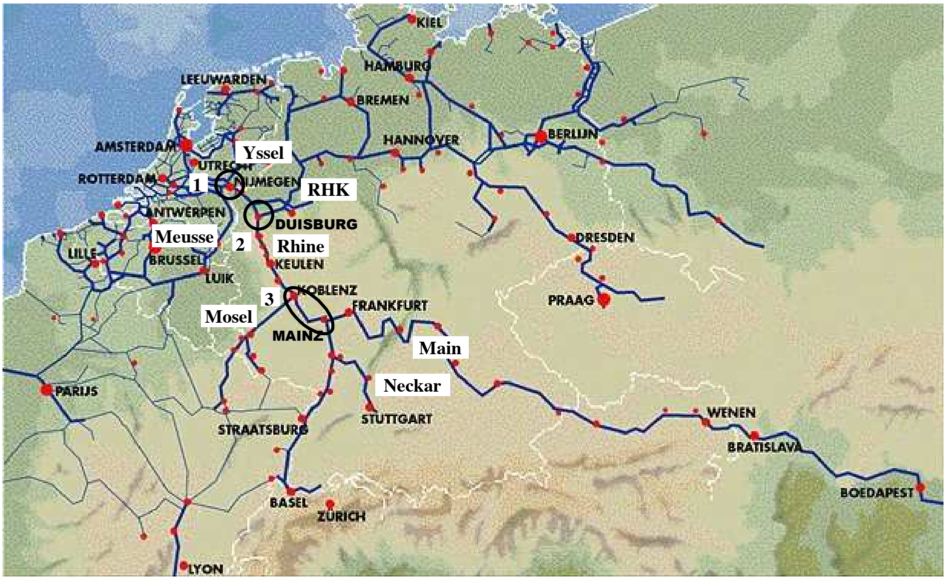
Many circumstances will influence the feasibility of a hub-and-spoke network for COB transport. A key element is the organization of the container exchange in the hub. It will be a challenge to exchange containers efficiently, reliable and fast, taking into consideration that also the sailing schedules of vessels from different spokes should be tuned in order to offer acceptable total transit times. The additional handlings in the hub result in additional costs, but these costs may be compensated by the improved cost performance on the network as a whole. By implementation of point-to-point services between the hub and spoke terminals the turnaround time of the vessel can be kept relatively small in order to make the vessel most productive, i.e. achieving economies of density, and the vessel size can be fully adapted to the waterway dimensions of the specific spoke, i.e. maximizing economies of scale. However, a pre-condition for this concept is also the availability of space: in the port basin to enable a direct exchange, and on land for temporary stacking of containers.

The conditions discussed suggest that such a network can only be developed on a large geographical scale level (pan-European), because the sailing distance should be large enough to achieve an economic feasible concept, which is also competitive to road transport. In addition, the backbone of the network should consist of crossing waterways that have reasonable navigable conditions. The well-developed services for COB transport in hinterland traffic should become a part of such a hub-and-spoke network. This can be useful to further rationalize these hinterland services, but it also provides a base cargo load to develop (new) spoke lines in which maritime and continental cargo flows can be bundled. This bundling of flows, which enables cost-efficient and frequent services, can be a self-reinforcing process.

In looking over the map of Europe there are not many places where such hub-and-spoke networks could be developed. In view of the arguments mentioned, the Rhine river should play a part in it. Such a network would logically cover at least some spokes to different seaports: Rotterdam, Antwerp, Amsterdam as well as some tributaries of the Rhine river, such as the Meuse and Yssel river in the Netherlands and/or the Rhine-Herne canal (RHK), the Neckar, Main or Mosel in Germany. Figure 4.6 indicates the regions where the hub terminal might be located.

If the details of the waterways, the operational characteristics of vessels and terminals as well as the container transport flows are known, models can be used to test the feasibility of specific configurations of hub-and-spoke networks in COB transport empirically. This will be the challenge in future research.

Figure 4.6 Indicative regions for a possible hub location



Region 1: Nijmegen.
Region 2: Duisburg.
Region 3: Koblenz/Mainz.

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5 Opportunities to improve container barge handling in the port of Rotterdam from a transport network perspective

Konings, R. (2007) Opportunities to improve container barge handling in the port of Rotterdam from a transport network perspective, in: *Journal of Transport Geography*, 15 (6), pp. 443 – 454. Copyright © Elsevier Science Ltd.

Abstract

This paper presents and evaluates an opportunity to improve the competitiveness of container barge transport in the hinterland of Rotterdam through a re-organization of container barge services. This re-organization improves the handling of barges in the port and consists of splitting existing services into a trunk line operation in the hinterland and collection/distribution operations in the seaport. A marginal cost model is used to demonstrate the potential net benefits of these revised services. The main conclusion is that these split services can improve the competitiveness of barge hinterland transport, but the effectiveness depends on several conditions. These conditions are first of all related to the design and organization of collection and distribution transport, but also to the characteristics of the trunk line operation in the hinterland.

5.1 Introduction

The quality of hinterland transport has become increasingly important for the competitiveness of a seaport. Shippers and carriers value the attractiveness of a port on not only the performance of the seaport, but also on its hinterland accessibility. This holds for the container transport market in particular. Containerisation has changed liner shipping spectacularly and affected seaports and their hinterland transport systems (De Langen and Chouly, 2004; Hayuth, 1981, 1982, 1987; Notteboom, 1997; Slack, 1985, 1999). Container shipping has enabled new kind of liner service networks such as the hub-and-spoke formation, putting pressure on the performance of hub ports and the feeder networks to these ports over sea and land. McCalla (1999) and Haezendonck and Notteboom (2002) argue that containerisation has increased the geographical market coverage of seaports to the extent that the concept of a captive hinterland is no longer valid. Ports are much more in competition to serve the same inland areas. Especially in Northwest Europe, where the distance of container ports to major cargo generating inland areas is not a very distinguishing factor, this has made hinterland accessibility a strategic matter.

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

The development of intermodal transport has given a new dimension to the hinterland transport issue. It can help keeping the port accessible by shifting cargo away from the congested roads to the waterways and railways. On the other hand the large transport volumes in seaports generate scale economies to operate cost efficient hinterland services to different destinations, which enables seaports to strengthen their hinterland position. These merits of intermodal transport have been addressed and analysed by e.g. Hayuth (1982), van Klink (1995) and Van Klink and van den Berg (1998).

In the port of Rotterdam intermodal barge transport plays an important role in hinterland transport. Since the mid eighties container barge transport has become a very competitive alternative to road and rail transport due to its ability to offer cheap and reliable transport services. Transport volumes in container barge transport have grown very rapidly over the last two decades. In the period from 1985 to 1995 barge traffic in the hinterland of Rotterdam grew from 200,000 TEU to about 1 million TEU. In 2005 more than 2 million TEU were transported, corresponding to a market share of 31% (www.portofrotterdam.com). Favourable natural conditions, such as the location of the port at the estuary of the Rhine River – Europe's most important inland waterway – have been a major asset for the strong development of hinterland transport by barge in Rotterdam. In view of increasing container volumes and congestion on the roads barge transport is of great importance to keep the port of Rotterdam accessible.

The strong position of container barge transport in Rotterdam is however not unchallenged. The quality of handling barges in the port greatly influences the performances of container barge services to the hinterland, and the present way of handling barges is far from optimal. The main cause for this inefficiency is that barges have to call at many terminals in the port when they visit the port of Rotterdam. This involves a lot of time, which could be used more productively, for example for sailing. In addition, it causes congestion and waiting times at terminals, because many barges call at the same terminal. Moreover, seagoing vessels also call at these terminals and these ships have priority over barges in handling and hence the waiting time of barges can increase. An additional problem is that when a delay arises at one terminal the barge may not catch the agreed time window for handling at the next terminal. So barge operators need to include large margins when planning their terminal visits to ensure reliable transport services. Altogether the duration time in the port is relatively long, which has a negative influence on the transit time and total cost of barge services and hence on the competitiveness of barge transport.

According to forecasts container throughput in the port of Rotterdam will increase from 9.3 million TEU in 2005 to 15.9 million in 2020 (Gemeente Rotterdam, 2004) and this will also boost volumes transported by barge. Much more barges will visit the port and hence problems with handling barges are likely to increase. Even nowadays long waiting times of sometimes more than 24 hours occur, and during the summer of 2004 these were the rule rather than the exception. The consequences became grievously clear as some barge operators felt forced to introduce a temporary surcharge to compensate for waiting time costs. Confronted with higher rates some shippers shifted their freight from barge to road transport.

Problems with handling barges in the port have not only occurred of late and so they have been studied before. In the research and development program INCOMAAS (*In*frastructure *Co*ntainers *Maas*vlakte), which focussed on the Rotterdam-Maasvlakte terminal area, opportunities to improve the handling of barges have been investigated (TRAIL, 1995a, 1995b). These studies addressed the options of centralised and decentralised handling of barges at the Maasvlakte area and also studied possible designs of barge terminal cranes. As a continuation of this program the idea of large-scale container barge transport using automated terminals was proposed and investigated (Wijnolst *et al.*, 1995; TRAIL, 1996). In the research program FAMAS (First All Modes All Sizes) focussing on a new terminal area at Rotterdam-Maasvlakte area (Maasvlakte II) that is still to be constructed, the same issues were addressed and studied again. This program resulted in a design of a dedicated barge terminal (GEM Consultants *et al.*, 1999). The proposed solutions in both research programs however are local-oriented instead of port-wide. In addition, some studies were carried out into new barge service systems: the floating container terminal (Tutuarima, 1993) and 'Waterbakfiets' (water carrier cycle) (RIL, 1996a), which could take over the collection and distribution of containers in the port from operators offering services between the port and the hinterland. The floating container terminal is never implemented and the Waterbakfiets is used for other purposes.[17]

In order to reduce waiting times at terminals the attention recently has shifted to improving the quality of information exchange between actors, the introduction of fixed time windows for barge handling at seaport terminals and better route planning of terminal visits. Promising research is carried out into a decentral (distributed) planning system based on multi-agent technology (Van Schuylenburg *et al.*, 2003; Schut *et al.*, 2004). This project is now in a pilot stage. Of course a better planning can improve the transport reliability and reduce the waiting times at terminals. Expanding the terminal capacity to handle barges is also an effective

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[17] The Waterbakfiets operations are carried out by two vessels operated by the company Van Uden Container Barging, which have a capacity of 81 TEU and 129 TEU respectively. These vessels are mainly used to reposition empty containers between terminals and empty depots, but not to collect and distribute containers between terminals. This happens only very incidentally. The total annual volume transported by the Waterbakfiets is about 70,000 TEU.

solution, just like the idea of fixed time windows to handle barges, although these measures can be adverse for the utilisation rate of the seaport terminals. Nevertheless, the time loss due to hopping from terminal to terminal will still remain in these solutions. Therefore, to accommodate container barge traffic more efficiently, it remains useful to look for alternative solutions regarding barge handling.

This paper presents a concept to improve the handling of barges in the port through a re-organization of container barge services. This idea assumes a split up of existing services into a trunk line operation in the hinterland and collection/distribution operations in the seaport. The paper discusses the conditions needed to successfully implement these revised barge services. It builds on previous work of Notteboom and Konings (2004), where the concept of revised network services has been presented. Here in this paper the merits of these new network operations are further discussed and tested by a model using empirical data. The approach is to explore the economic feasibility of these network operations rather than to evaluate concrete system solutions, such as the idea of the floating container terminal.

The paper starts with a description of the characteristics of the present barge hinterland services. Then the idea of re-organizing these services is explained in terms of costs and benefits. After that a cost model is used to empirically demonstrate the potential net benefit of these revised services. Next the conditions for implementation are discussed. The paper ends with conclusions and recommendations for future research.

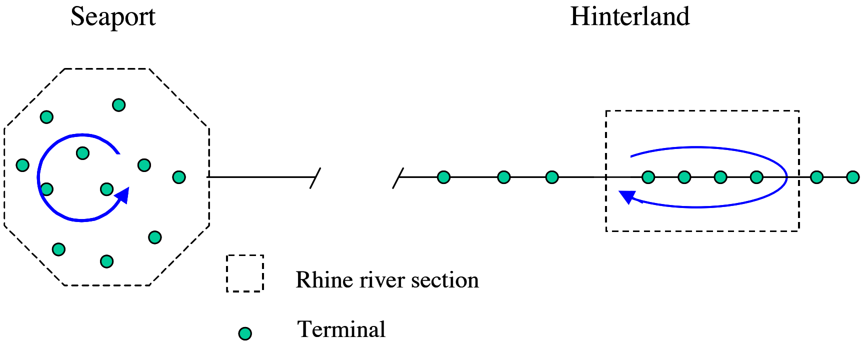
5.2 Characteristics of the present barge hinterland services

Three major markets or trades can be distinguished regarding container barge transport through the port of Rotterdam (A&S Management *et al.*, 2003):

- *Rhine river trade*: transport of containers between the port of Rotterdam and large industrial and customer areas in Germany and parts of France and Switzerland. In 2004 about 950,000 TEU were transported in this hinterland corridor of Rotterdam. About 30% of this transport volume is generated in the Lower Rhine river region (from Emmerich to Bonn), 50% in the Middle Rhine river region (from Koblenz to Wörth) and 20% in the Upper Rhine river region (from Strasbourg to Basel) (see also Figure 5.6);
- *Rotterdam – Antwerp trade*: transport of containers between the port of Rotterdam and Antwerp. This flow is a result of the main porting strategies of deep-sea carriers. Transported volume in this trade was about 950,000 TEU in 2004;
- *Domestic trade*: transport of containers between Rotterdam and inland areas in the Netherlands. In 2004 transport volume in this trade exceeded 700,000 TEU.

In all three markets regular and frequent services are offered. The current network characteristics of transport services in the Rhine river trade are more or less identical. A vessel sails between the seaport and a dedicated region in the hinterland, i.e. the Lower, Middle or Upper Rhine river basin. In the hinterland region about 3 to 5 terminals are visited, while the average number of terminal calls in the seaport is about ten (see Figure 5.1). In domestic trade usually only one terminal is visited in the hinterland.

Figure 5.1 Typical pattern of barge transport operations in Rhine river hinterland transport



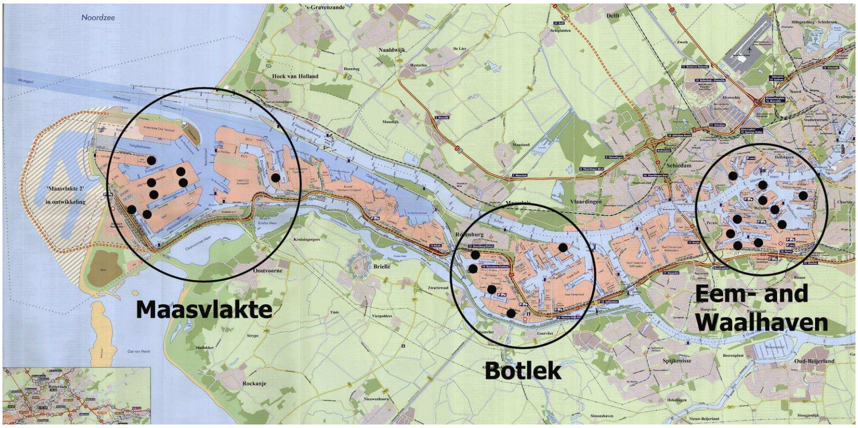
The consequence of visiting a limited number of terminals in the hinterland is that numerous terminals must be visited in the seaport, unless a batch of containers from one hinterland terminal would be large enough to completely fill a vessel with containers that all have the same destination terminal in the seaport. However, this is unlikely, because containers from this batch have different overseas destinations and are generally transported by different deep-sea lines.

The port of Rotterdam has about 30 container terminals including empty depots. These terminals are spread over a rather large port area. Spatial clusters of terminals are found in the area of Eem/Waalhaven, Botlek and Maasvlakte (see Figure 5.2). The distance between Eem/Waalhaven and Maasvlakte is about 40 km, which corresponds to a sailing time of about 2.5 hours. So it is evident that calling at several terminals can be a time-consuming process.

According to a large survey on barge hinterland services held in the nineties (RIL, 1996b) and validated through some recent interviews with barge operators, the typical roundtrip time of a vessel that operates in the Rhine hinterland includes on average 60% sailing time, about 30% duration time in the port and at inland terminals and about 10% of time is reserved to absorb possible delays, mainly those caused at the terminals in the seaport. The share of sailing time is relatively small and this reflects some kind of unproductiveness, because sailing is the most important business to generate income to the barge operator. Since these are average figures the share of sailing time will be larger in sailings to the Upper Rhine region, because of the longer distances to the port of Rotterdam (about 650 to 850 km) and smaller for destinations in the Lower Rhine region, because of the smaller distances to the port (about 250 to 350 km). During a vessel's stay in the port of Rotterdam (30 to 36 hours), 150 containers on average are loaded and unloaded, which takes about 12 hours handling time. The other 18 to 24 hours are spent sailing from one terminal to the other and waiting at the terminals.

The call size at terminals in the port varies a lot, but in 50% of all terminal calls, less than 6 containers are loaded or unloaded. Of course such calls put a relatively high burden on time consumption. Another observation is that the call size at terminals in the Eem/Waalhaven area is generally smaller than in the Maasvlakte area.

Figure 5.2 Location of barge terminals in the port of Rotterdam



Source: Adapted from port of Rotterdam

5.3 Re-organisation of barge hinterland services: splitting of operations

As Figure 5.1 shows, the present barge hinterland services are operated in networks, which partly have collection and distribution characteristics, i.e. in the seaport, and partly have a line network structure, i.e. in the hinterland. A vessel performs both kinds of operations. Splitting these functional operations into a trunk line and collection/distribution service could potentially improve the performance of the total service. The vessels that serve the hinterland can reduce their turnaround time and so improve their productivity. In the collection/distribution network container flows can be bundled for terminals of destination and origin in the port, which enables a more efficient and prompt handling of barges. However, the collection and distribution of containers in the port also involves time and costs. These revised services will be feasible if these so-called feeder costs can be sufficiently compensated by savings in the hinterland transport.

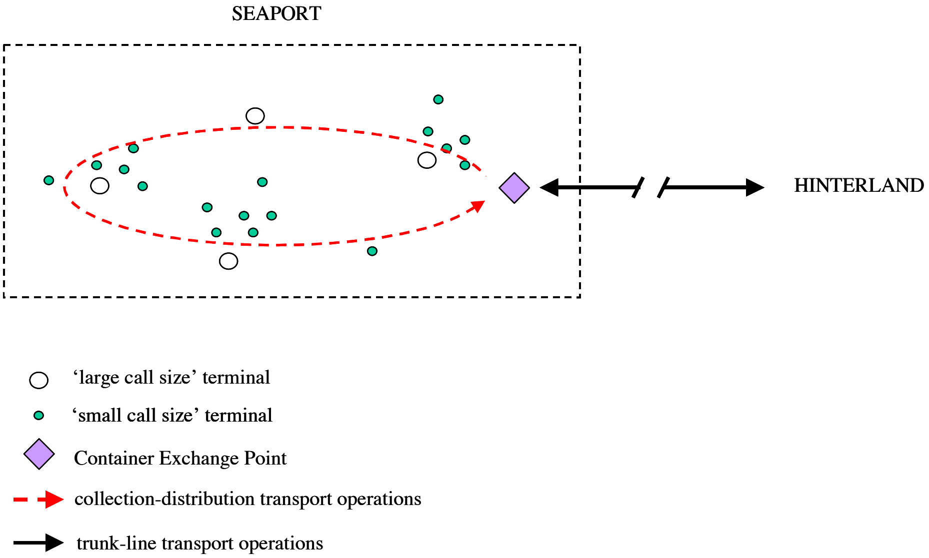
Service models for collection/distribution transport

Splitting existing operations into a trunk line part and a collection/distribution part can take different forms. Dependent on the number of terminals the hinterland vessel has to visit in the port and the organizational structure of the collection/distribution transport, three basic models for collection/distribution transport can be distinguished:

1. 'Container Exchange Point' service model: central handling of hinterland vessels and centralized organization of collection/distribution transport

In this model the handling of hinterland vessels is completely centralized, that is to say, all vessels call at one terminal that functions as a container exchange point. Here containers are transhipped to other vessels operating in the port, which distribute (and collect) containers to their destination (and origin) terminal in the seaport (see Figure 5.3). The potential improvement in turnaround time of hinterland traffic vessels is maximal. A disadvantage is that *every* container is handled an additional time, which also makes high demands on this exchange terminal in terms of capacity and sorting functions. On the other hand, because transport volumes are large, this offers opportunities to sort containers according to their destination terminal and to transport these containers in a cheap shuttle service. The idea of this model has much in common with the possible role of what Slack (1999) defines as satellite terminals. Slack postulates that setting up such terminals in the hinterland could be useful to consolidate individual shipments and hence to reduce congestion in the port through the provision of efficient connections between the satellite terminal and the mainline terminals in the port. So instead of a location in the seaport a nearby inland terminal could also be considered as a possible location for this Container Exchange Point.

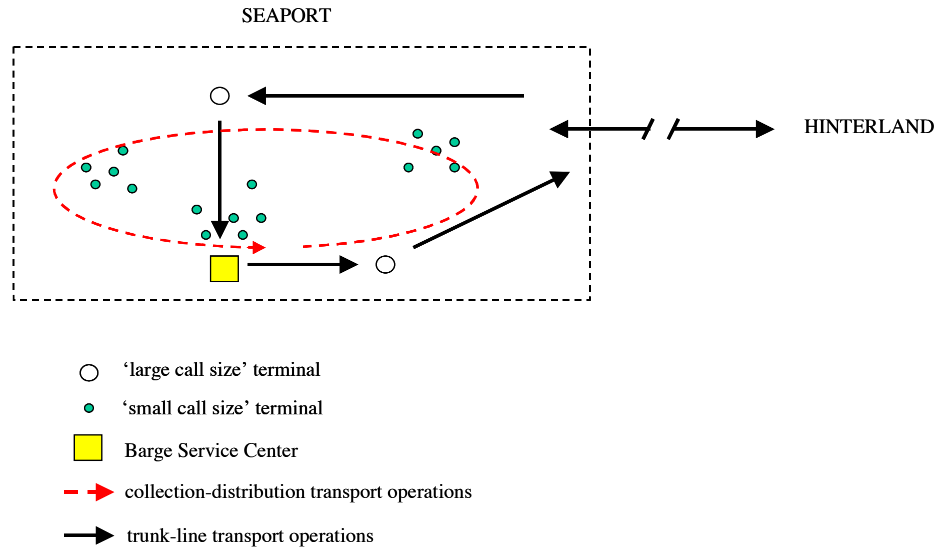
Figure 5.3 Collection/distribution transport via a Container Exchange Point



2. 'Barge Service Centre' service model: decentralized handling of hinterland vessels and centralized organization of collection/distribution transport

The Barge Service Centre model assumes that hinterland vessels call at a limited number of seaport terminals. This choice of terminals will be based on call size. Hinterland vessels will call only at terminals for which they have a large number of containers to load and unload. Small container batches for other terminals are brought to a Barge Service Centre from where these containers are transported to their destination terminal (see Figure 5.4). In this model the savings in turnaround time will be smaller, but also the operational costs of collection/distribution transport will be lower. Collection/distribution transport is organized centrally at the Barge Service Centre, so container flows can be bundled efficiently in collection/distribution services.

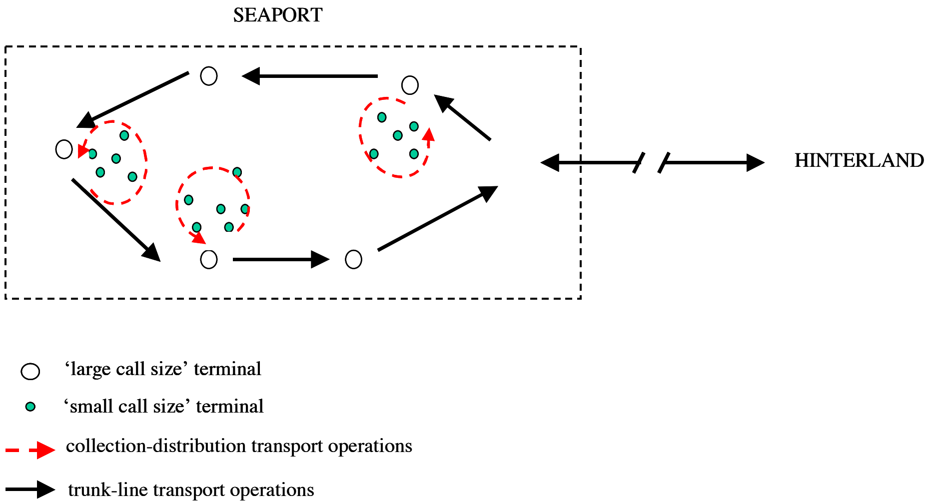
Figure 5.4 Collection/distribution transport via a Barge Service Centre



3. ‘Multi-hub terminals’ service model: decentralized handling of hinterland vessels and decentralized organization of collection/distribution transport

In this model, just like the ‘Barge Service Centre’ model, hinterland vessels also call directly at terminals for which the call size is sufficiently large, but collection/distribution of small container batches takes place locally (see Figure 5.5). This means that a hinterland vessel picks up and drops containers at a terminal which is the origin or destination terminal of these containers (‘large call-size’ terminal), but it also uses this terminal to drop and pick up small container batches for nearby terminals, which are not being visited by the hinterland vessel. These ‘small call-size’ terminals are served locally by vessels operating in a collection/distribution transport system. The organization of this transport can therefore be characterized as a decentralized process. In contrast to the previous models this model offers fewer opportunities for economies of scale and scope in collection/distribution transport, but the transport distances are smaller. In addition, this service model is more flexible to use. This model looks interesting for the port of Rotterdam, because the location of terminals in the port is spatially clustered.

Figure 5.5 Collection/distribution transport via multi-hub terminal



5.4 Evaluation model

To show the potential advantages of splitting existing barge hinterland services into a trunk line operation and collection/distribution operations a model is elaborated. The principle of this model, derived from the work of Dekker and De Jong (1989), is a marginal cost/revenue analysis that enables a flexible and convenient way to calculate the feasibility of these split services under different conditions.

The starting point for the analysis is the investigation of benefits. The benefits arise from a time saving in the port for the barge operator because of fewer terminal calls and, related to that, larger call sizes. These circumstances can be used to make a vessel more productive either by:

1. increasing the frequency of services or
2. increasing the vessel size.

By increasing the service frequency the quality of barge services improves, but it also improves the cost performance (see Konings, 2003). Implementation of larger vessels is a direct way to reduce the costs of barge services, i.e. lower sailing costs per unit through economies of scale.[18] Which option is preferred depends on the amount of time saving, but

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[18] The effectiveness of these productivity improvements is straightforward in case transport volume increases, but this is not a necessary condition to save on fleet operation costs. If a vessel can increase its frequency of services, it can make more roundtrips per year saving on the total number of vessels needed in the fleet. Increasing the vessel size can mean a substitution of small vessels by a smaller number of larger vessels, because the time saving in the seaport allows compensating for a larger turnaround time of larger vessels without overrunning their sailing schedule. In other words, scale economies may arise without increasing the fleet capacity (in terms of container slots).

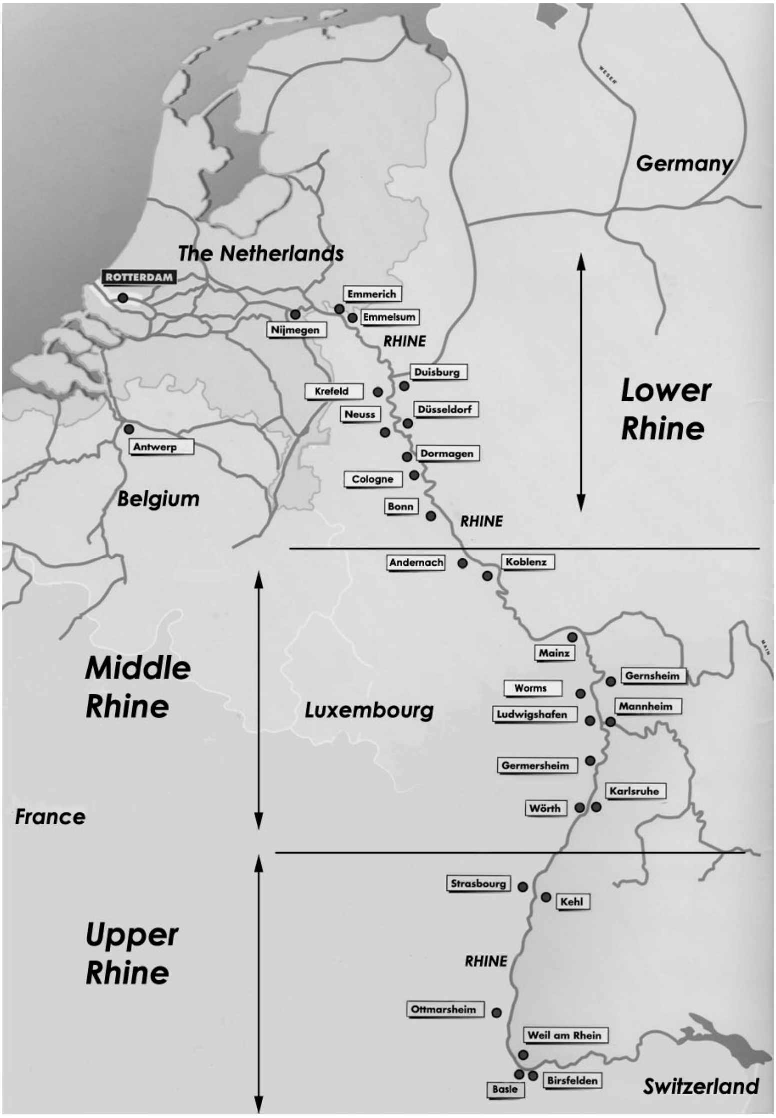
also on the turnaround time of a vessel in relation to its sailing schedule and vessel size (Konings, 2003).

Container vessels sail according to a fixed schedule, usually related to a weekly pattern. In the Rhine river hinterland traffic barges make two roundtrips per week, one roundtrip per week or one roundtrip in two weeks (see Figure 5.6). In domestic hinterland traffic barges can usually make two roundtrips per week. It is obvious that substantial time savings are required to enable an increase in frequency. If the turnaround time of a vessel could be reduced by one day, this could have a large impact on short distance barge services, but it would not be effective for those services at long distances. On the other hand, there are limits to increasing the vessel capacity. Increasing the size of a vessel also means increasing the total loading and unloading time. Very large vessels may be unable to maintain their weekly pattern and the transit time of containers would become too large.

5.4.1 Reference situation

In the current situation, or the reference situation, we assume that a vessel that operates in hinterland services calls at 10 terminals in the port. Five terminals are visited in the Eem/Waalhaven area, two terminals in the Botlek area and three terminals at the Maasvlakte area (see Figure 5.2). We assume that these visits are scheduled in such an order that each of these port areas has to be visited only once, so that disturbances in the planning of terminal visits do not result in significant additional sailing time. For such a route through the port the time spent sailing in the port is about 8 hours. Data on the waiting times of vessels at terminals were obtained from a survey held among bargemen in 2003 (Koenis, 2003), which showed that the average waiting time per terminal is about one hour. This means that the total time a vessel spends on sailing and waiting in the port is about 18 hours. We assume a barge service in which a vessel makes one roundtrip a week, which corresponds to a hinterland service to the Middle Rhine region. The transport capacity of the vessel is 200 TEU.

Figure 5.6 Partition of the Rhine river according to the turnaround time of vessels



Note: Rhine container terminals anno 2006

Lower Rhine section:	two roundtrips per week.
Middle Rhine section:	one roundtrip per week.
Upper Rhine section:	one roundtrip per two weeks.

Source: Adapted from Gemeentelijk Havenbedrijf Rotterdam, 1994

5.4.2 Collection/distribution transport via multi-hub terminals

Let us assume that according to this collection/distribution service model the number of terminal calls can be reduced from 10 to 4 calls. Now two terminals are visited in the Eem/Waalhaven area, one terminal in the Botlek area and one terminal in the Maasvlakte area. In addition, the waiting time per terminal is also smaller, i.e. 45 minutes, because of a lower risk of the accumulation of delays. The total time used sailing (5.25 hours) and waiting (3 hours) is 8.25 hours, and as a result the total time saving is about 10 hours. These 10 hours can be used for additional container moves. If we assume a crane productivity of 15 moves per hour, this means that 150 additional containers can be loaded or unloaded. Since every container transported must be loaded onto and unloaded from the vessel once, 75 extra containers can be transported. Based on the distribution of containers of different size (20ft and 40ft units) this corresponds to a transport volume of 120 TEU. To transport this extra volume additional vessel capacity is needed. Since in barge transport vessels are usually operated with high utilization rates, a substantial increase in transport volume requires a larger vessel. The potential increase in turnover, therefore, also involves additional vessel operating costs. The estimation of these costs will be derived from the costs of chartering a larger vessel. If we know that the charter costs for a vessel with a capacity of 200 TEU is about 17,500 Euro per week, we can estimate that increasing the capacity by 120 TEU will raise the charter costs by 7,000 Euro. Finally, it is assumed that 25% of all the containers must be feedered, i.e. collected and distributed to other terminals in the port. This share seems small, but if about 50% of all terminal visits have a call size less than 6 containers, this is a realistic assumption.

If we know the transport tariff of the barge hinterland service and the costs of the collection/distribution service, it is now possible to evaluate whether these split services are beneficial or not. The potential net benefit can be described in a general formula expressing the benefits (additional turnover) and the costs (additional charter costs and feeder costs):

$$\text{Net benefit} = TV_{add} * P_{ht} - MC_{chart} - S_{ft} * TV_{tot} * P_{ft}$$

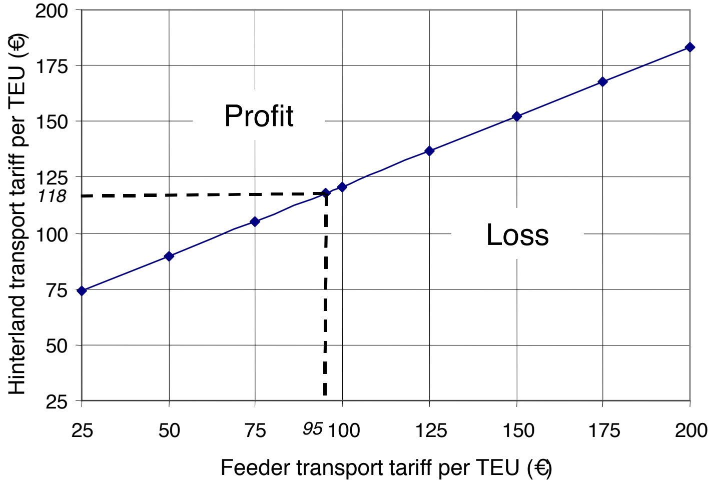
TV_{add} :	additional transport volume (in TEU)
P_{ht} :	transport tariff hinterland transport per TEU (in €)
MC_{chart} :	marginal costs of chartering additional vessel capacity (in €)
S_{ft} :	share of feeder transport in total transport volume (%)
TV_{tot} :	total transport volume (in TEU)
P_{ft} :	tariff of feeder transport per TEU (in €)

By setting this net benefit to zero break-even situations for the current and new (split) barge hinterland services can be presented as a function of different hinterland transport tariffs and feeder transport tariffs. The higher the feeder transport tariff is, the higher the hinterland transport tariff must be to make split services profitable. Figure 5.7 shows the results of this case study. The combinations of hinterland transport tariffs and feeder tariffs left of the break-even line are profitable solutions. The combinations to the right of the line are not profitable. Currently feeder transport does not exist, except in very rare cases in which barge operators of hinterland transport outsource the collection and distribution of 'late' containers to a barge operator active in short-haul operations in the port, so that they can keep their sailing schedule. The port activities of this barge operator (Van Uden Container Barging) consist of repositioning empty containers between terminals and empty depots. The tariffs for these barge operations are about 95 Euro and can be considered a good estimation of what the tariffs for feeder transport could be at the moment. This tariff, which is a cost for the hinterland barge operator buying these services, covers sailing and terminal handlings. If the feeder transport tariff is 95 Euro, the break-even situation for the present and new barge services would be realised with a transport tariff of 118 Euro per TEU for the hinterland service (see also Figure 5.7). Since we assumed that the vessel makes one roundtrip a week, this means that we have to consider the tariffs of barge services between Rotterdam and destinations in the Middle Rhine river section. The current tariff for services to these destinations range from 125 to 140 Euro per TEU, which is above the break-even tariff of 118 Euro (see Table 5.1). So in this situation a reduction of terminal calls would be a profitable solution.

The situation for services to the Lower Rhine river section is different. Here two roundtrips a week are made, so the additional transport volume increases from 120 TEU to 240 TEU, but the transport tariffs are much lower: the tariffs vary from 50 Euro for the short-distance destinations to 100 Euro per TEU for destinations at longer distance in this river section. In Table 5.1 can be seen that, given the estimated present feeder transport tariff, a hinterland transport tariff of at least 71 Euro would be necessary to be profitable. This means that the feasibility of split services is ambiguous: for distant destinations, such as Bonn, the hinterland tariffs are sufficiently high for profitable services, while for near by destinations, such as Duisburg, the solution will not be cost effective.

The same analysis can also be performed for services to the Upper Rhine region. The tariffs of these long-distance services are of course higher (ranging from 160 to 190 Euro), but due to a greater turnaround time for the vessel (one roundtrip in two weeks) additional transport volume is also smaller (60 TEU) and so is additional revenue. As a matter of fact these revenues are too small to compensate for the feeder costs. Only a sharp reduction of the feeder tariff would make split services feasible to this Rhine river section (see Table 5.1).

Figure 5.7 Break-even situations of present and new (split) hinterland barge services according to the 'multi hub terminals' service model used in barge services to the Middle Rhine river section



5.4.3 Collection/distribution transport via a Barge Service Centre

In this collection/distribution model all small container batches are transhipped at the Barge Service Centre and are feedered in a collection/distribution network from and to their final terminal of origin and destination. Hinterland vessels still call directly at terminals when the call sizes are large.

If we compare this service model with the multi-hub-model in this model the hinterland vessel has to visit one more terminal, i.e. the Barge Service Centre to drop and pick up small container batches. The major difference, however, is the organizational structure of collection/distribution transport. In theory collection/distribution transport can be organized more efficiently, because of a central collection/distribution centre.

In the present situation interterminal transport of empty containers by barge is offered by Van Uden Container Barging as a flexible line service, i.e. the schedule of the barge services depends on the fluctuations in transport demand. These barge services cover the whole port area. The services have an irregular pattern and the tariffs are hardly related to distance: tariffs range from 15 Euro per TEU to 20 Euro per TEU for the longest distance, i.e. between the Eemhaven and the Maasvlakte area. Organising these services via a Barge Service Centre may reduce the sailing costs of feeder transport, but substantial savings cannot be realized because these tariffs are already quite low.

The use of a central collection/distribution centre puts another asset of this service model forward: concentrating the exchange of containers between the trunk line and collection/distribution services in one centre or terminal offers opportunities for more efficient handling operations. As the share of handling costs in the total feeder costs is about 80%, cost savings here would be most effective.

To summarize, if the Barge Service Centre model can realise a reduction of feeder transport tariffs, either by savings in sailing and/or handling costs, then this model would almost always perform better than the multi-hub terminals model. How much this reduction of feeder transport tariffs could be has not been extensively analysed in this study. However, as Table 5.1 shows the difference between the break-even tariffs of the multi-hub and Barge Service Centre model are in favour of the multi-hub model (and are caused by one less terminal call in this model), but they are small. If the Barge Service Centre model can induce a feeder tariff reduction from 95 to 75 Euro, it would become the most preferable model in every situation.

5.4.4 Collection/distribution transport via a Container Exchange Point

The ultimate solution of splitting a barge service into a trunk line operation and collection/distribution operations would be the situation in which the hinterland vessel has to call at only one terminal in the port. This service model has been defined as the Container Exchange Point Model.

A Container Exchange Point could be located near the landside entrance of the port, e.g. somewhere in the Eem/Waalhaven area. Hinterland vessels would then gain a maximum time saving in the port. Time spent in the port would drop from 18 hours to about 1 hour, assuming that the capacity of the Container Exchange Point is sufficiently large to avoid long waiting times. Again this time saving could be converted into additional revenue through the transport of extra containers. Knowing the transport tariffs for hinterland transport, the break-even situations can be recalculated again. Assuming a feeder tariff of 95 Euro per TEU the break-even transport tariff for services to the Middle Rhine region would be 233 Euro per TEU, which is much higher than the present tariffs to this region (see Table 5.1). The increase of potential transport volume is large (204 TEU) and so is the revenue, but the fact that all containers must be transhipped and feedered at a price of 95 Euro per unit is prohibitive in this service model. As Table 5.1 shows, this model would also be unprofitable for services to destinations at the Lower and Upper Rhine river region.

Table 5.1 Summarized results on the feasibility of new (split) hinterland barge services using different service models in the port (HUB, BSC, CEP*): break-even (or minimal required) hinterland transport tariffs at different feeder transport tariffs (in €/TEU)

Hinterland services to:	Lower Rhine			Middle Rhine			Upper Rhine		
Feeder transport tariff	HUB	BSC	CEP	HUB	BSC	CEP	HUB	BSC	CEP
50	51	55	99	90	98	148	167	184	246
75	62	67	135	105	115	195	192	211	315
95 (present tariff)	71	76	164	118	128	233	212	233	370
100	73	78	171	121	131	242	217	238	384
125	84	90	207	136	148	289	242	265	453
Range of present hinterland transport tariffs:	50 - 100			125 - 140			160 - 190		

* HUB: multi-hub terminals, BSC: Barge Service Centre, CEP: Container Exchange Point.

Recapitulating the results on the feasibility of all three service models, both the multi-hub terminals and the Barge Service Centre model appear promising, but under the specific circumstances that have been assumed, these models would only be profitable if applied to hinterland transport services to the Middle Rhine region, i.e. middle-distance services. Overall the multi-hub terminals model shows the best performance, but if the Barge Service Centre model can realise its potential savings in feeder transport it can surpass the performance of the multi-hub terminal model.

5.4.5 Sensitivity analysis on the results

As regards the feasibility of the service models many parameters play a part. In order to test the influence of parameter assumptions on the results a sensitivity analysis was carried out. As a starting point for this analysis the parameters and results of the multi-hub terminals model were taken. The following assumptions have been successively altered: the number of terminal calls (scenario A), the crane productivity (scenario B), the share of feeder transport (scenario C), the cost of feeder transport (scenario D) and the cost of chartering additional vessel capacity (scenario E). The results are shown in Table 5.2. Evidently a reduction of number of terminal calls, feeder and charter costs, as well as a smaller share of feeder transport, i.e. less smaller container batches, will lower the break-even tariff and hence improve the feasibility of split barge hinterland services. On the other hand higher crane productivity also makes the conditions for split services more favourable. A change of the conditions in this direction would also bring the feasibility of split services for Lower and Upper Rhine river services closer to reality. However, changing these conditions are to a large extent beyond the control of barge operators.

Table 5.2 Effects on the break-even hinterland transport tariff under changed assumptions (basis scenario assumptions relate to the multi-hub terminals model for services to the Middle Rhine river region)

Scenarios	Reference situation	Basis scenario (HUB MR service)	**A**	**B**	**C**	**D**	**E**
# terminal calls	10	4	**3**	4	4	4	4
- sailing time (h.)	8	5,25	4,75	5,25	5,25	5,25	5,25
- waiting time (h.)	10	3	2,25	3	3	3	3
Crane productivity (moves/hour)	15	15	15	**20**	15	15	15
Share feeder transport (%)	-	25	25	25	**20**	25	25
Feeder costs (Euro/TEU)	-	95	95	95	95	**55**	95
Marginal charter costs (Euro/week)	-	7000	7000	7000	7000	7000	**6000**
Break even hinterland tariff (Euro/TEU)	-	118	109	94	106	93	109

5.5 Opportunities and threats for the implementation of trunk line and collection/distribution services

As we have seen in the previous section there are several variables which can produce an effect on the feasibility of these split services, but also less tangible conditions may come into play if decisions on implementation have to be made. From this point of view the following opportunities and threats are distinguished:

Cost structure of feeder transport

The costs of feeder transport services play a decisive role in the feasibility of split operations in barge hinterland services. Looking at the cost structure of the present feeder transport services the sailing costs are just 15 – 20 Euro per TEU, while the handling cost are about 70 – 80 Euro per unit. These handling costs cover two moves, i.e. to load and unload a unit. In order to further improve the attractiveness of split services, solutions to reduce the handling costs would be most effective. If it would be possible to have just one move, i.e. board-to-board transhipment, already a large cost saving would be gained. The organisation of board-to-board transhipments can, however, be a logistical complex process, in particular in case several vessels are involved. One of the requirements is that the sailing schedules of vessels calling at the transhipment terminal are well tuned (see also Konings, 2006). From this perspective operating push boat – push barge formations in feeder transport seems more promising than motor vessels. Given that these formations can be uncoupled, the cheap push barges can act as a floating stack unit awaiting to receive containers while the expensive push boat can remain productive by sailing.

Increase of time spent in the seaport

Possible time savings depend on the reduction in the number of terminal calls and consist of a reduction in the sailing and waiting times at terminals. It is clear that the waiting time carries more weight in potential savings than sailing time. It is not unlikely that the average waiting time per terminal will further increase in the near future, due to increasing throughput in the port of Rotterdam. A substantial expansion of terminal capacity is planned by the enlargement of the Maasvlakte area (Maasvlakte II), but this is not expected to become operational before 2013. These new terminals will reduce capacity problems at existing terminals, but they will be established at a new location. Consequently the number of terminals in the port rises and this enhances the chance that barges have to hop between terminals. This would mean an increase of the time spent in the port and thus making split services more attractive.

Construction of a barge – feeder terminal at Maasvlakte area

To increase the handling capacity for deep-sea vessels in the medium term, the port of Rotterdam has decided to relocate the handling of barges and small sea vessels (feeder vessels) partially to a new, to be built terminal at the existing Maasvlakte area. The construction of this terminal should be realised in the year 2008. It can be used for barges having a small number of containers aboard for one or several terminals located at this terminal area. From there containers can be transported to these terminals by terminal transport equipment, i.e. multi-trailer trains. This process would reduce the number of terminal calls for barges and would be very similar to the idea of what we called the multi-hub terminal model except that collection and distribution of containers takes place by a road-like transport system.

Such an organisation for dealing with small call sizes was tried before at the Maasvlakte area, but it failed because the terminal operator could not pass the costs of terminal transport on to the shipping line. Shipping lines prefer barges to call at their own terminals, despite of small call sizes, in order to avoid these additional terminal transport costs. Moreover, shipping lines strive for a high utilisation rate of their own deep-sea terminals. These interests of shipping lines could undermine the idea of this barge – feeder terminal.

Freight consolidation in the hinterland

Traditionally the leading principle for container barge hinterland services has been to load containers in the hinterland for all destinations in the port, resulting in the pattern of a small number of terminal calls in the hinterland and many calls in the seaport. Encouraged by the dramatic waiting times at terminals in the port barge operators have started to rethink these operations: shifting round some of these operations! That is to say, if a vessel only loads those containers in the hinterland that are destined for only one or a few terminals in the port, this will improve the handling process in the port significantly. According to this approach more calls in the hinterland may be needed to sufficiently fill a vessel in this way. Alternatively, barge operators can collaborate to load such 'dedicated' vessels together[19].

A major condition to enable this consolidation of freight in the hinterland efficiently is a change in method of working of inland terminals. Instead of stacking containers according to seaport destination (Rotterdam or Antwerp), containers should be stacked by seaport terminal destination. This makes container stacking a more complex activity and may also demand for additional space. It will be a great challenge to get the inland terminals their operational processes adapted.

Decreasing time margins in sailing schedules

Due to heavy competition in container barge transport, sailing schedules are increasingly based on fast turnaround times for the vessels, that is to say, the margins in sailing schedules tend to be kept small, while as the situation in Rotterdam demonstrates, there is actually a need for larger margins. As a result, it becomes increasingly difficult for a vessel to cope with incidents and delays without over-running its sailing schedule. This wish to have small time margins could therefore support the idea of feeder transport.

Organizational and logistical complexity of the split barge hinterland service

Outsourcing of the collection/distribution transport in the port will also entail additional administration, which increases the probability of errors. Moreover, the collection/distribution services should be well tuned to the trunk line services in order to remain competitive for the existing barge hinterland services in terms of the transit time of containers.

Loss of control in the transport chain

The introduction of collection/distribution transport services would eventually mean that a barge operator active in hinterland transport would have to give up a part of his transport

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[19] If several barge operators have a small batch of containers to load at an inland terminal that have the same destination terminal in the seaport, it is more efficient to bundle these batches instead of each barge operator collecting his own container batches at several inland terminals.

operations. Another barge operator would take over responsibilities in the port, which could weaken the commercial relations of barge hinterland operators with the deep-sea lines, who are also their clients. Barge operators might therefore take a conservative attitude towards feeder transport, considering it a threat to their strong position in the chain of hinterland transport.

'Phantom' revenues

An important barrier for implementation might be that barge operators may have doubts about the possibilities to capitalize the time savings in the port. As discussed earlier, time savings are only useful if they can be used productively. In other words, barge operators want to be sure that the costs of feeder transport can indeed be earned back by more productive or cost-efficient trunk line transport services. Of course this is much easier to accomplish in a market that is still growing than in a stagnating market. However, there are also limits to increasing the capacity of vessels. A much larger vessel may be unable to sail according to the weekly patterns (see Figure 5.6), because of an increase in total loading and unloading time. This time schedule problem can to some extent be avoided if the number of terminal visits in the hinterland is also reduced, because loading and unloading a number of containers at one terminal is always less time-consuming than handling the same number of containers spread over several terminals. However, this would assume that demand for container transport at one hinterland terminal is sufficiently large to fill a vessel.

5.6 Conclusions

Cheap and reliable barge services are of strategic importance for the port of Rotterdam in accommodating hinterland container traffic. As we have addressed in this paper, the way barges are currently handled in the port is far from optimal and this inefficiency endangers the future role of barge transport in hinterland traffic. In order to improve barge handling in the seaport a re-organization of container barge services has been proposed and evaluated in this paper. This re-organization consists of splitting existing services into a trunk line operation and collection/distribution operations in the seaport.

It has been demonstrated that the barge operator in the hinterland transport could improve its productivity and hence gain substantial additional revenue if the number of terminal visits in the port could be reduced. This reduction of terminal calls can be achieved if these barge operators avoid terminal visits that involve a small call size. This means that small container batches having different terminal origins and destinations should be re-organized through specific collection/distribution transport services. The additional revenue can be sufficient to more than offset the additional costs arising from these collection/distribution services. The total effect can be a cost improvement of container barge transport in the hinterland. The potential benefits however depend on specific conditions. In particular, the distances in the hinterland services and the market tariffs of these services are distinctive factors. Of course the design and organization of these collection/distribution services is a crucial element, because it determines the costs of these services. A cost reduction would further improve the attractiveness of these split services to the hinterland. The most promising solution for such a reduction can be found in the transhipment costs of containers. If transhipment between the trunk line section and the collection/distribution section can be achieved by one move (i.e.

board-to-board transhipment) this would substantially improve the competitiveness of these split services.

The Barge Service Centre model and the Container Exchange Point model seem to offer the best conditions to accomplish efficient handling operations, because they can be developed as a dedicated facility. However, an inherent disadvantage of the Container Exchange Point model is that *all* the containers must be handled more times, which has serious effects on the costs. Further research is needed to investigate terminal designs, which enable efficient transhipment processes. Also the best location of such a Barge Service Centre needs to be further explored. The issue of exchanging containers efficiently in the Barge Service Centre does not only touch upon questions about the most convenient terminal lay-out and equipment for handling, but also concerns the types of vessels to be used. The use of push barges can offer some very interesting advantages in a collection/distribution transport system, but in this field there is also further research to be done.

The advantages of this new barge transport service concept to improve the efficiency of barge handling may go well beyond the interests of the barge sector. If trucks operating in long-distance hinterland transport could also use the exchange terminal facility as a container drop-off and pick-up point instead of visiting the different terminals in the port these truckers may avoid road congestion that particularly occurs in the port terminal areas. This would improve the efficiency of container trucking and the port accessibility. The added value of this additional function will however strongly depend on the location of the exchange terminal. Moreover, the use of an exchange terminal could improve the performance of the marine terminals. Since the new barge transport concept is focused on realizing large call sizes – and the average productivity of handling containers in large call sizes is higher – the crane/quay productivity at marine terminals can increase. In addition, the concept could support a better utilization of space at marine terminals: if the exchange terminal can also facilitate a storage function for (empty) containers it can contribute to a reduction of the dwell time of containers at marine terminals. Considering the challenge of the port of Rotterdam to increase the productivity and to reduce the spatial pressure and congestion at its container terminals, these opportunities are major additional assets of this alternative approach to barge handling in the port.

To conclude, barge handling innovations can only succeed if market parties accept them. It is important that the involved actors, i.e. barge operators, skippers and terminal operators, are convinced that improving the handling of barges is a win-win situation for all parties. A further deterioration of the performance of barge handling in the port is apparently needed to increase the sense of urgency for structural solutions, and to bring innovative barge handling concepts closer to reality.

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6 Terminals and the competitiveness of container barge transport

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Abstract

Low cost operations have traditionally formed the competitive edge of inland shipping and, due to the exploitation of these comparative advantages the barge sector has succeeded to gain a substantial market share in container transport. To improve the competitiveness of container barge transport the cost and quality performance of terminals play a major role.

Terminal handling is a major cost frontier, because the share of terminal costs in the total chain costs of barge transport is relatively large. Especially the handling of barges in the seaport is expensive. To enable new types of cost efficient barge services additional functions of a terminal come into play, i.e. there is a new challenge for the functional performance of barge inland terminals.

This paper explores the future requirements and opportunities of barge terminals to further improve the competitiveness of container barge transport. Here the relationship between barge network design and terminal design is relevant. Based on a review of the major cost drivers in barge handling and the role of terminals in barge service networks, new challenges for container barge handling and possible solutions are discussed. A major conclusion is that a differentiated approach is needed in developing new terminal and handling concepts. The major drivers for this differentiated approach are the container volumes to be handled and the position of the terminal in the network.

6.1 Introduction

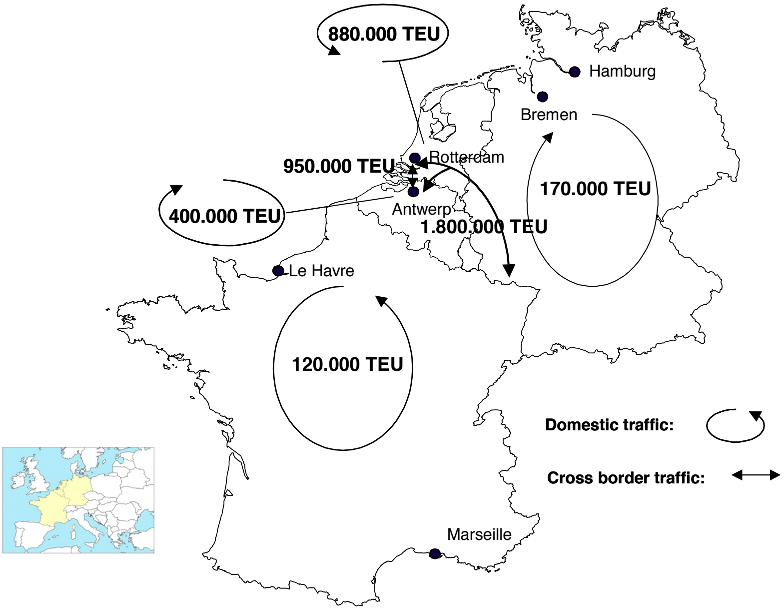
In a relatively short time barge transport has become a well-developed mode for transporting containers in Northwest Europe. Reliable and low cost barge services together with the provision of additional logistic services, such as the organization of drayage operations, have increased the interest in container barge transport as an alternative for road transport (De Vries, 2000). Since the early nineties container barge transport has shown spectacular growth figures: total traffic in Europe crossed the 1 million TEU mark around 1991, the 2 million TEU mark in 1996 and the 3 million TEU mark in the year 2000 (Deplaix, 2002). The estimated barge traffic in 2004 exceeded 4 million TEU. Although these volumes are significant they represent, roughly estimated, only 1% of the total transport performance (in tonne-kilometres) in Europe and a share of 8% in the total performance of the barge transport sector (Deplaix, 2002).

Geographically the development of container barge transport has been dictated by the position and quality of inland waterways and the fact that this transport business is strongly related to *deep-sea* traffic. Container transport by barge is predominantly a transport mode to move maritime containers between the seaport and its hinterland. Due to the presence of the Rhine river it has been mostly developed between the seaports of Rotterdam and Antwerp and the hinterland in Germany. In 2004, total container traffic on the Rhine accounted for 1.8 million TEU. Due to its close relation with *deep-sea* traffic container barge transport also strongly developed as a mode for feeder traffic between the ports of Rotterdam and Antwerp. In 2004 about 950,000 TEU were shipped between these ports.

For a long time these international traffic flows have set scene for the container barge transport market. However, in the nineties also domestic hinterland services were started, demonstrating that barge transport can also compete with road transport on much shorter distances than previously assumed. Since then the number of services and transported volumes have rapidly increased. In 2004 about 880,000 TEU were shipped by barge in domestic hinterland traffic in The Netherlands and about 400,000 TEU in Belgium. Currently barge transport has a share of approximately 30% in hinterland container traffic in Rotterdam, while rail counts for about 10% and road 60% (www.portofrotterdam.com). The modal split for Antwerp is comparable to Rotterdam (www.portofantwerp.be). The transported volumes by barge in Germany (170,000 TEU in 2004) and France (130.000 TEU in 2004) are modest and hence the barge share in the hinterland modal split is also small. In the port of Le Havre it was 6% and in Hamburg 2% in 2004 (http://www.havre-port.net/pahweb.html; http://www.hafen-hamburg.de/). Hinterland container transport by barge, however, is also on the way up in these countries. An overview of these major flows is given in Figure 6.1.

The development of container barge transport has been successful so far, but there is a great challenge to further increase its market share significantly. The rapid growth of container throughput of ports is putting pressure on the capacity of their hinterland infrastructure. In particular the roads around the ports are already often clogged. For instance the port of Rotterdam envisages a throughput of 15.9 million TEU in 2020 (Municipality of Rotterdam and Port Authority Rotterdam, 2004), which corresponds to a growth of 70% over the period 2005-2020. Such a growth figure for hinterland road transport would dramatically increase congestion and air quality problems. A much larger share of barge transport (next to rail transport) is therefore needed to keep the port accessible. In addition there is a need for barge transport to play a role in freight transport that is eligible for intermodal transport, but has no relation with the seaport. This continental freight transport market is even more dominated by road transport.

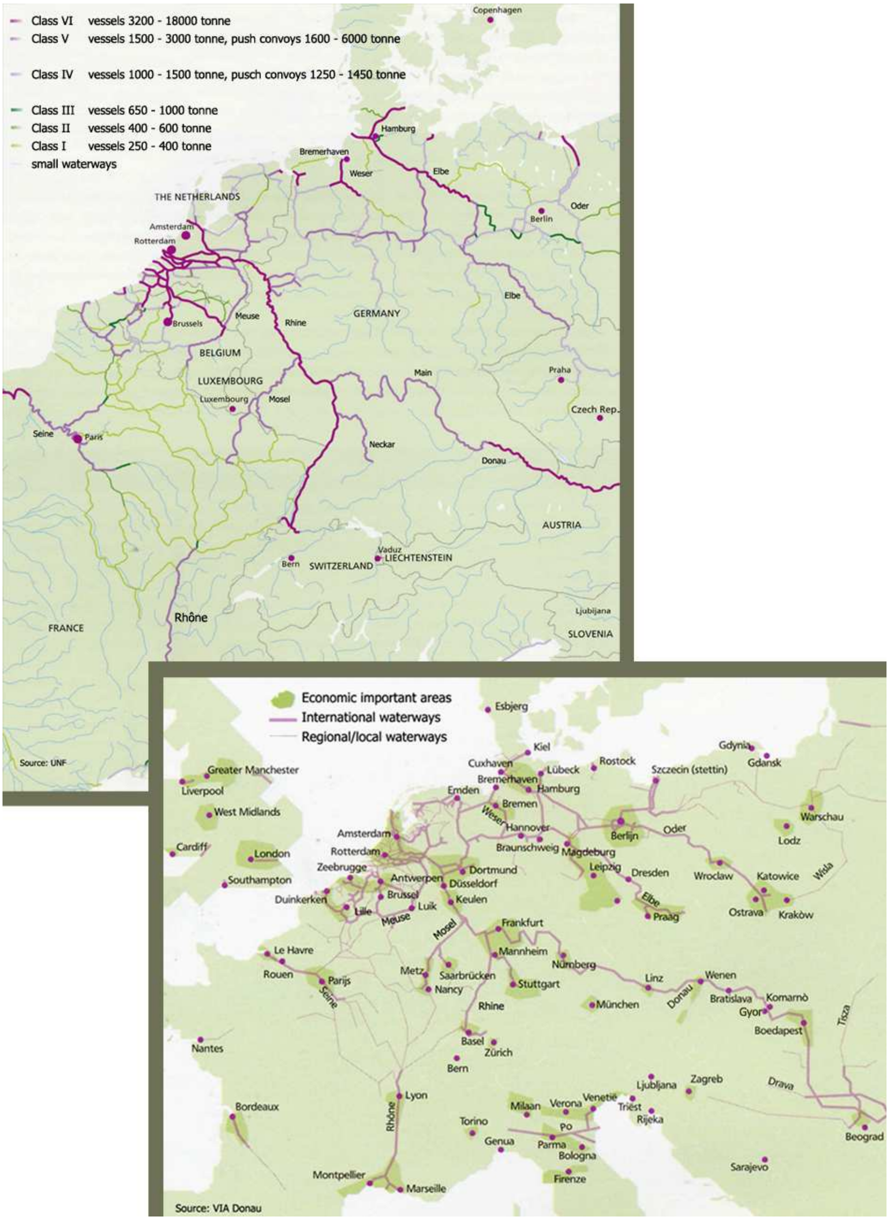
Figure 6.1 Cross border and domestic container barge traffic in Northwest Europe (2004)



Source: Drawn by the authors

A modal shift towards barge transport is not a matter of course, but requires a permanent high performance of container barge services. Increasing transport volumes create opportunities for efficiency improvements in existing transport services offered by barges. On the other hand increasing its market share also assumes expanding into new geographical markets and hence the development of new barge transport services that can compete with road transport. A precondition for such a development is the availability and quality of the waterways. As Figure 6.2 shows, the network of waterways in Northwest Europe is quite extensive, but there is also a large variation in navigational conditions.

Figure 6.2 Classification of waterways in Europe and the position of major waterways in relation to important economic centres



Source: Via Donau and VNF (adapted from De Vries, 2006)

New type of barge operations can be an answer to this challenge of market development (Notteboom and Konings, 2004), but the role of terminals in improving the attractiveness of container barge transport may not be overlooked.
First, the share of terminal handling costs in the total barge transport chain costs can be significant. Dependent on the transport distance (length of the barge haul and the pre- or post-truck haul) it can easily amount to 30% (Macharis and Verbeke, 2004). The greater proportion of these costs on short distances makes handling costs a serious cost frontier to gain market share in short distance transport.

Secondly, the quality of services of terminals is gaining importance in the total performance of the barge transport chain (Van den Arend *et al*., 2000; Wiegmans, 2003; Macharis and Verbeke, 2004). The reliability and transit time of intermodal barge services are strongly influenced by the terminal performance. Rodrigue (1999) argues that nowadays terminals even play the most important role in improving the efficiency in transport chains. He addresses the role of terminals in synchronizing flows having different geographical scales, different volumes and different time patterns. The increasing role of services is also visible in the expansion of activities of terminals from transhipment only to several additional services such as empty container storage, container cleaning, stuffing and stripping and sometimes even freight warehousing and assembling activities. Offering these logistical services appears to be a way to commit customers to the terminal and is therefore of strategic importance to increase the attractiveness of intermodal barge transport. The fact that the operation of a barge terminal in the hinterland and its barge services to the seaport are often in one pair of hands underlines these intertwined interests. Such developments confirm the notion that terminals are no longer merely a link in the transport chain, but are becoming an integrated part of the logistical chain.

Considering this important role of terminals in container barge transport chains the question we address in this paper is: what are the future requirements and opportunities of barge terminals to improve the competitiveness of container barge transport? In elaborating this question we first start with an overview of current barge terminal handling processes showing the major cost drivers in barge handling and clues for cost improvements (section 2). The role of terminals for the competitiveness of barge transport can not be considered in isolation, but should be part of an analysis of barge service networks. Improving the performance of barge transport services may also require different qualities of terminals. In other words, the relationship between barge network design and terminal design comes into play here. This relation is being discussed through an overview of the developments in barge service networks and the role that barge terminals play in these networks (section 3). Based on the analysis of current terminal handling processes and the future requirements of terminals to enable more efficient and new types of barge transport services three main areas are distinguished where innovations in container barge handling would be promising and some possible innovations in these areas are discussed (section 4). The paper ends with general conclusions (section 5).

6.2 A closer look at the terminals for container barge handling

There is a great difference between the equipment and working methods of terminals to handle barges in the seaport and in the hinterland.

6.2.1 Barge handling in the seaport

The present way of handling barges in the seaport is not very efficient. On the one hand this has a technical background and on the other hand it is related to the organization of handling barges.

The terminal handling costs for barges are dependent on the type and number of handlings that have to be performed at the terminal. In general two types of handling or barge moves can be distinguished. Containers can be picked up from the stack by a straddle carrier and transported to a crane that tranships the container aboard of a barge. Alternatively a straddle carrier can pick up a container from the stack and put it on a multi-trailer, which transports a number of containers to a crane to load aboard of a barge. If the distance between container stack and barge is significant (usually at large terminals), the latter process is preferred. However, it is more complicated, in particular compared to road transport where usually only a straddle carrier is needed to handle trucks. These circumstances, and especially the use of expensive quay cranes, explain that a container handling (move) is about 30% more costly for a barge than for a truck (Macharis and Verbeke, 2004).

The high transhipment costs are also explained by the use of quay cranes that are operated to handle *deep-sea* vessels. Due to their large size these cranes are much more expensive than dedicated barge cranes. Moreover, their productivity in handling barges is lower, because of their height, and related to that, their sensitivity to swing (causing a longer cycle time). Nevertheless, for reasons of optimal berth and crane utilization many barges are handled by *deep-sea* cranes, but the increasing role of barges in hinterland transport has now gradually also resulted in investments in barge quay cranes at *deep-sea* container terminals.

Apart from these technical issues the way in which barge handling is currently organized is mostly far from optimal. This organizational inefficiency is in particular manifest in the port of Rotterdam and Antwerp and is related to the presence of many container terminals that are spread out over a large area in these ports. The bottom line of this inefficiency is the fact that barges have to visit multiple terminals in each of these ports (in Rotterdam sometimes more than 10 terminals). This involves a lot of time, which could be used more productively, for example for sailing. Moreover, as a result of visiting multiple terminals the call size is on average relatively small, leading to a relatively long handling time per terminal and hence a lower terminal productivity. In addition, as many barges call at the same terminal this causes congestion and waiting times at terminals. Furthermore, seagoing vessels also call at these terminals and in general these ships have priority over barges in handling and thus the waiting time of barges can increase. An additional problem is that when a delay arises at one terminal the barge may not catch the agreed time window for handling at the next terminal. So barge operators need to include large margins when planning their terminal visits to ensure reliable transport services. Altogether the duration time in the port is relatively long, which has a negative influence on the turn around time and total cost of barge services and hence on the competitiveness of barge transport.

6.2.2 Barge handling in the hinterland: inland terminals

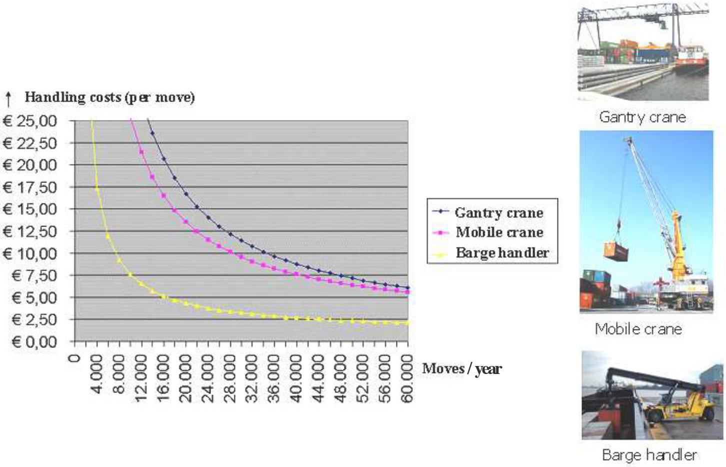
The development of container barge transport has been really stimulated by the introduction of container terminals in the hinterland. The first inland barge container terminal was established in Mannheim along the Rhine river in Germany and dates from 1968 (Van Driel, 1993). However, significant growth of container barge transport took off from the early 1980s as a number of established ports along the Rhine invested in container transhipment facilities at their existing sites and also new terminals were set up within the vicinity of existing ports or even at new locations along the Rhine. No less than twenty new Rhine terminals were opened in the period 1980 – 1987 (Notteboom and Konings, 2004). Since then the number of terminals has steadily increased. In Germany currently there are more than 35 terminals including sites along other rivers than the Rhine river (De Vries, 2006). In the meantime other destinations in the hinterland of Rotterdam and Antwerp were opened up, because also barge container terminals in The Netherlands and Belgium were set up. Today in The Netherlands more than 25 terminals exist and Belgium records 12 inland terminals (www.inlandshipping.com; www.binnenvaart.be).

Many of these terminals are more or less identical in terms of type of equipment, lay out and working methods. Differences in type of equipment may be the result of differences in development phase and, related to that, the size of the terminal. The starting point for establishing a new inland terminal and barge service is usually the presence of one or a few launching customers, which guarantee a minimum (threshold) transport volume to start operations and hence limit exploitation risks. In that initial phase, where volumes are still small, simple and rather inexpensive terminal equipment may be chosen, for instance a reach stacker (possibly secondhand) or a general-purpose crane that is mixed used for both container and general cargo transhipment.

Looking at the cost structure of an inland barge container terminal the major investment costs consist of infrastructure, i.e. quay construction and grounds, and equipment, i.e. cranes and internal transport vehicles. Personnel and depreciation costs are the most important cost categories in the operational costs. About 75% of the total operational costs are fixed costs. This means that the number of moves strongly determines the costs per move: as the number of containers transhipped increases the cost per container can considerably decrease. Figure 6.3 shows this relation between transhipment volume and costs for three different types of transhipment means. Note that these costs represent direct costs, excluding the costs for quay construction etc.

The barge handler, which is a special reach stacker, has the lowest cost per unit for each transhipment volume. The capital costs of gantry cranes and mobile cranes are much higher and hence the handling costs are higher, particularly when the volumes are small. However, if handling volumes increase, beside costs, handling capacity and efficient land use at the terminal are gaining importance, and this makes the gantry crane the most preferred facility. Most inland barge terminals in Europe are equipped with one gantry crane (and some having two cranes) and dependent on their size they have ancillary terminal transport vehicles, e.g. reach stackers.

Figure 6.3 The relationship between transhipment volume and costs



Source: Data from equipment suppliers (reference date: 2005), gathered by the authors

As mentioned, the transhipment volume is of great importance for the profitability of a terminal. Van Klink (2004) shows that, given a handling tariff of 16 Euro per move, an annual volume of 30,000 moves is needed for break-even. He assumes a 'green field' development of a terminal, which means full investment costs, while handling equipment would consist of one barge handler only. A study of Decisio (2002) showed a break-even volume of 20,000 containers for a 'full cost' terminal and 14,000 containers for a 'low cost' terminal, both operating a gantry crane. However, in this study rather high handling tariffs were assumed. Studies by Wiegmans *et al.* (1999) and Kessel and Partner (2002) are consistent with the findings of Van Klink.

In practice the operational costs, and hence also the break-even volumes, of an inland barge container terminal can vary significantly between different terminals due to different circumstances (Van Klink, 2004). Many terminals have been set up with government subsidies, which lower the initial net investment costs. In addition, if a terminal for instance can be developed along an existing quay or if land can be leased instead of bought, this makes a great difference, as well as the possibility to use second hand equipment. Offering additional services such as container storage can generate additional revenue to cover a part of the terminal operation costs. Although these strategies can reduce the break-even transhipment volume, still a considerable volume is needed for profitable operations. In general the volume required to operate an inland terminal is more critical to start a hinterland container barge service than the volume needed to operate a barge vessel in that service.

6.3 Developments in barge service networks

A further improvement of the competitiveness of container barge transport requires improvements in the quality of barge services and cost reductions. Lowering the costs is of particular interest to improve the competitiveness in the short distance transport market (see also Bontekoning and Priemus, 2004). As far as quality is concerned the following improvements are desirable:

- *Reducing door-to-door transport time*; as barge transport is a relatively slow mode this means that any time loss at terminals should be minimized (see also Rodrigue, 1999) because the terminal is the linking pin between barge and pre- and post-haulage by truck. Avoiding intermediate terminal stops also reduces the total transit time.
- *Higher reliability*; the majority of the European waterways still have a large reserve capacity and are able to accommodate substantial traffic growth without causing congestion. Barge transport is reliable, but since the handling time of barges in the seaport is capricious this is a threat for the reliability of barge services. Barge operators have to keep sufficient large margins in their sailing schedule. The costs of unreliability have become of growing importance, mainly as a result of the emergence of just-in-time deliveries.
- *Higher transport frequencies*; as shippers become more and more demanding a very frequent service (preferably once every day) is a pre-requisite to be an alternative for road transport. A high transport frequency can also partially compensate for the disadvantage of the slow speed of barge transport. The intervals between services become smaller, thereby reducing the waiting time for freight. Moreover, higher frequencies can also have a positive effect on the required stack facilities at terminals.
- *More destinations to serve*; the position and quality of the waterway network of course strongly determine the potential areas that can be served, but increasing the market share also assumes expanding the geographical coverage. This might be possible if the opportunities of small waterways are better utilized.
- *Accessibility to the waterway network*; the most competitive service area of a terminal, i.e. the region in which barge transport can offer cost competitive services to door-to-door road transport services, is usually an area having a circumference of 15 km around the terminal. At a greater distance from the terminal to the customer the costs of pre- and post truck haulage often become too high. Despite that already a substantial number of terminals have been established this suggests that there is room for additional ‘terminals’ to attract new cargo flows.

As will be shown, the type of service networks can play a role to achieve these cost and quality objectives.

In the development of container barge service networks a number of phases can be distinguished, in which also the role and characteristics of terminals have evolved (Notteboom and Konings, 2004).

In the very early days (early 1970s) only small containerized volumes were carried at irregular intervals by conventional barges from Rotterdam to conventional transhipment points on the upper part of the Rhine (Basel and Strasbourg) and the middle part of the Rhine (Mannheim and Karlsruhe).

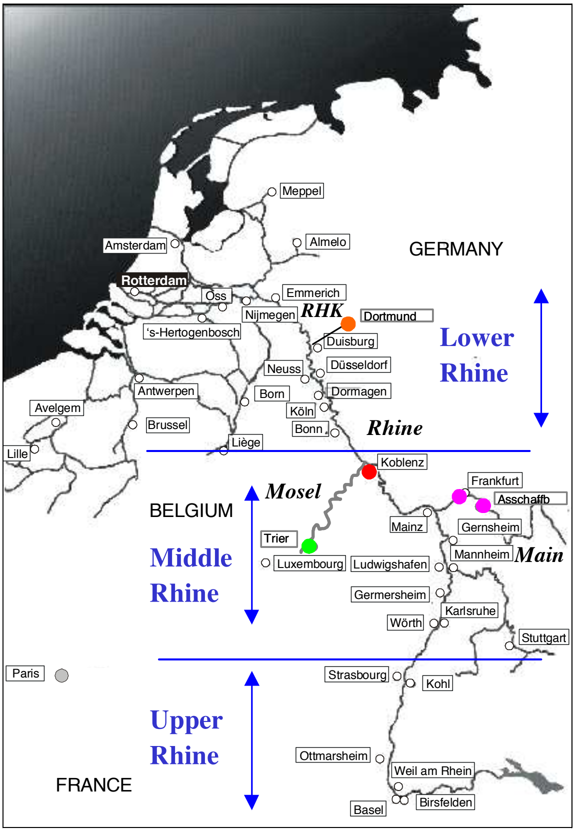
In the second phase (mid 1970s until mid 1980s) scheduled container line services gradually developed. For operational reasons these services were set up per section of the Rhine river, i.e. the Lower Rhine (as far as Bonn), the Middle Rhine (from Koblenz to Wörth) and the Upper Rhine (from Strasbourg to Basel) (see Figure 6.4). Soon these services also got a fixed departure schedule. The number of terminals along the Rhine increased rapidly, and terminals were increasingly established as facilities to tranship containers exclusively. Barge operators became also involved in establishing terminals: setting up single-user terminals could well support their line services. In addition, independent terminal operators emerged by setting up common-user terminals.

Typical for the next phase (mid 1980s until mid 1990s) was the willingness of barge operators to co-operate to raise the level of service and prevent ruinous competition, which resulted in jointly operated services. As a result the frequency of services increased to each of the three service areas along the Rhine (having three to five terminal visits in the hinterland and many calls in the seaport). As a result of growing transport volumes a limited number of direct point-to-point services were also developed (e.g. from Rotterdam to Duisburg). New terminals were now also developed along the Lower Rhine, confirming increasing competitiveness of barge transport on shorter distances (< 500 km). In this period also container barge transport between the ports of Rotterdam and Antwerp came to prosperity, as barge was discovered as an interesting mode for this feeder traffic of the *deep-sea* lines. Large transport volumes, large barges and high frequencies were and still are the major success factors for barge transport in this trade (A&S Management, 2003). These services take place between *deep-sea* terminals of Rotterdam and Antwerp and can be defined as semi-point-to-point services (or point-to-point services with limited local collection/distribution), because they generally have a limited number of terminal visits within the seaports.

In the fourth phase (mid 1990s until 2005) the types of barge services have become more diversified and also the service area has been expanded to outside the Rhine river corridor and the Rotterdam – Antwerp trade. Domestic hinterland services were started in The Netherlands (1995) and in Belgium (1996) and more recently in France (in the hinterland of Marseille and Le Havre) and Germany (in the hinterland of Hamburg). Almost all these domestic hinterland services are offered as a point-to-point service, i.e. a direct service between the inland terminal and seaport without intermediate stops. This has much to do with the transit time. The transit time should be kept small for these barge services on rather short distance, because of heavier competition with road transport. The fact that the exploitation of the barge service and the terminal are usually in one hand also fosters a direct service.

Along the Rhine river corridor the increasing transport volumes have resulted in a rationalization in the number of terminal visits in the hinterland and have enabled the introduction of larger barges (e.g. motor vessels having a capacity of 400 TEU or even more). In addition, some new types of barge services were gradually implemented, mainly as a way to serve areas along the tributaries of the Rhine more efficiently. In these so-called trunk-feeder services containers are shipped in regular (trunk line) services to ‘cross road’ terminals where these containers are transhipped to a feeder service to arrive at their destination terminal. These kinds of services were developed to Trier (along the Mosel), Frankfurt and Asschaffenburg (along the Main) and Dortmund (along the Rhine-Herne canal, RHK) (see Figure 6.4).

Figure 6.4 The Rhine river and its major tributaries



Source: Adapted from Gemeentelijk Havenbedrijf Rotterdam, 1992

Direct services from the seaports to these destinations are not so attractive, because either the transport volumes are still rather small or the waterway imposes restrictions on the capacity / vessel size (e.g. caused by bridge height or lock size) to operate a vessel that is sufficiently large to offer cost-efficient services. Due to the fact that containers destined for these tributary destinations are bundled with containers for other destinations along the trunk waterway (Rhine), the service frequency can still be high, although the flows to these tributary destinations can be small. On a small scale containers are transhipped to a large inland terminal (e.g. Duisburg) where containers destined for other Rhine terminals are transhipped to a line service visiting those upstream-located terminals. In these combined (trunk-feeder) services transhipment is usually performed through temporary stacking of containers on the quay or occasionally through a board-to-board handling (which saves the cost of one additional handling). The cost of this additional intermediate transhipment can be compensated by savings in network operations (sailing costs).

During this past decade the most striking changes at terminals have been that a number of terminals have been seeking complementarity between rail and barge transport by realising connections to the rail network (e.g. along the Rhine river Emmerich, Neuss, Duisburg, Mainz and Mannheim). In offering possibilities for combinations of barge-rail services they have addressed their position for being a hub for multimodal services. Furthermore, in reaction to the increasing size of vessels new cranes have become larger. Most of those new cranes are now also able to handle vessels with the standard width of 11.80 m side by side. The extension of services at terminals, including stocking facilities for container cargo at inland terminals, is typical for this fourth development phase of container barge transport. These developments at terminals indicate that many terminals have become more focussed on new ways to attract additional cargo flows and to handle large transport flows.

In the next phase (from 2005 to 2015) a further optimization of existing barge services and the development of new types of service network configurations can be expected. On the one hand it is likely that the point-to-point services, enabling the best performances in terms of costs, transit time and reliability, will gain importance as container transport growth shapes the conditions to offer such services. On the other hand the increasing number of terminals will create conditions to revise barge operations assuming that a hierarchy in terminals will emerge (see also Notteboom and Konings, 2004). Some selected strategically located terminals will obtain a hub status with important exchange functions (not only between barge and rail, but also between barges) and serving large and on long distance located markets, while other terminals become subordinated to these hub terminals in particular serving local and regional markets. This configuration will meet the demand for large transport volumes to a selected number of terminals which might be served directly by very large vessels even with high frequencies, and the demand for fine-meshed transport to small terminals with fast small to medium-sized vessels.

To some extent this structure is already visible for trunk-feeder services, although the applications are limited yet. However, it would become much more prominent through the introduction of hub-and-spoke barge networks, where container flows between origin and destination terminals are directed via a strategically located main (hub) terminal. Since the hub-and-spoke network is pre-eminently suited to implement new services between origin-destination pairs for which the transport flows are too small to run a direct (point-to-point) barge service it can support market expansion.

These new barge network developments seem to offer promising opportunities to increase the competitiveness of container barge transport, but they also imply important challenges for the future functionality of barge terminals.

6.4 New challenges for container barge handling

In view of the role of barge handling in the total intermodal barge transport chain and its specific position in barge service networks, three main areas can be distinguished where innovations in container barge handling look promising to increase the competitiveness and hence the market share of container barge transport.

6.4.1 Barge handling in the seaport

Volumes that need to be handled in the seaport are large (and still growing), but they are dealt with in a fragmentary way. Furthermore, the transhipment costs are high and the process is time-consuming. The challenge here is to develop concepts that are able to handle large volumes in a cheap and fast way.

Barge Express

Already in the mid 1990s a concept was proposed, named Barge Express, to improve the cost and quality performance of barge container handling and barge sailing in the hinterland transport of Rotterdam. To reduce sailing costs the concept assumes maximizing the scale of operations, i.e. using large push barges (144 x 22,8 metres having a capacity of 624 TEU or 72 x 22,8 metres having a capacity of 280 TEU to be used in a two barge formation). The size of these push boat/push barge(s) formations would enable sailing in the Rhine up to Mainz (see Figure 6.4). A reduction of container handling costs is realised by automation of the loading and unloading process. The barges are equipped with cell guides to facilitate an automatic loading and unloading process, which makes Barge Express a real integrated concept for container barge transport and handling (see Figure 6.5).

The (un)loading process is supported by computers, automated quay cranes, automated guided vehicles (AGVs) and automated stacking cranes (ASCs). These elements are all based on proven technology and are already used at the Delta terminal in the port of Rotterdam, except for the automated quay crane. However, its technology is known. In order to maximise the productivity of the large-scale transport units the number of visiting terminals is preferably limited. The system is aimed to offer point-to-point services between marine terminals in the seaport and barge terminals in the hinterland. In the seaport the Barge Express terminal has no quay stacking facilities, because loading and unloading of push barges is a simultaneous process: after AGVs arrive at the Barge Express terminal to load a push barge, the released AGVs are used to load containers from the unloading push barge. In this way terminal transport can be optimised through combining pick up and delivery trips. At the Barge Express terminal in the hinterland the loading and unloading of barges is a sequential process. The push boat arrives with a push barge for unloading and immediately leaves with another push barge loaded earlier. When a container arrives at the terminal by truck it can be moved directly from the truck in the push barge, which then acts as a floating stock. Containers arrived by barge and to be picked up by truck are first moved into a stack by AGVs and ASCs. In other words, the Barge Express terminal in the hinterland will have an important storage function.

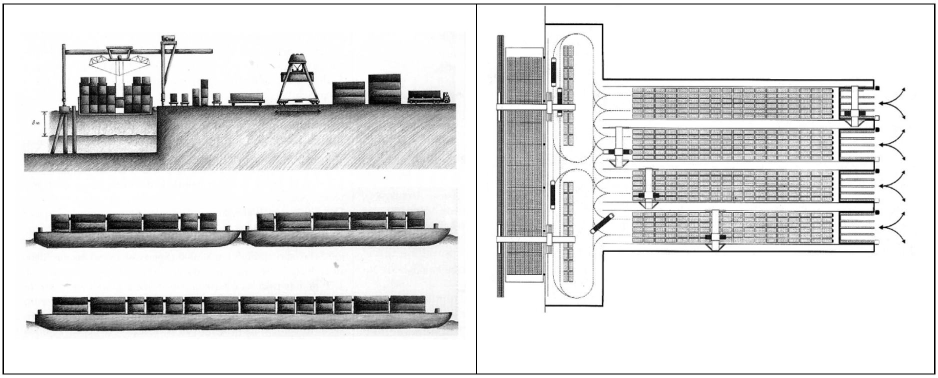
The sailing speed of pushed convoys will be on average about 15 km/h. The system capacity depends on the number of push boats and push barges that are implemented as well as the transport distance of services. One push boat and three large push barges can offer a daily service in two directions up to a distance of 80 km, which means a daily transport capacity of 1248 TEU. One of the three push barges acts as a floating stock facility at the hinterland terminal enabling the push boat to have a short turnaround time in the hinterland. This push barge will be transported in the next daily service.

Preliminary studies have shown that the Barge Express system could bring savings in the total barge chain costs (seaport terminal costs, sailing costs and inland terminal costs). These savings range from 15 to 22 Euro per 40ft container, which could be a 10% to 15% reduction in the total costs (TRAIL Research School, 1996).

The investment costs and investment risks are rather modest due to the fact that proven technology is used. The push boats can be chartered on the spot market, while the construction of large push barges equipped with cell guides is relatively simple. In case the concept would fail the dedicated barges could be easily transformed into barges suitable for transport of other type of cargo. The automated vehicles and stacking cranes could still be used to transport and handle containers in the container yard.

At the time this concept was proposed and studied – in 1996 – container transport volumes between the port of Rotterdam and large existing inland terminals (the port of Duisburg acknowledged as the most promising location) were found too small to develop such a large-scale container transport concept economically. A barge express terminal in Duisburg would require additional volumes originating from other distant Rhine regions, but the associated higher pre- and post haulage transport costs would offset the cost savings achieved in the river leg. Looking over the volume growth of Rhine barge traffic over the last decade and the development in Duisburg in particular, such a concept would deserve re-consideration.

Figure 6.5 Barge Express system (vessels, cranes and terminal lay out)



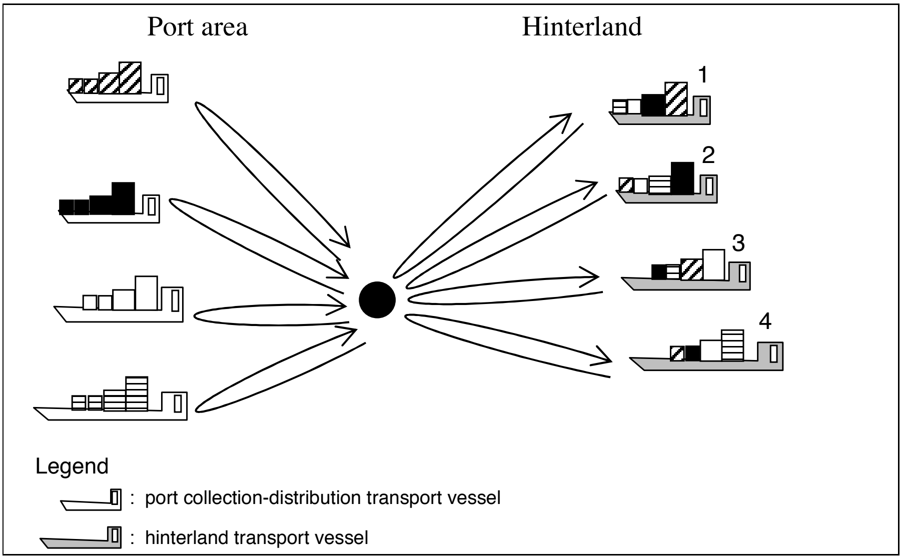
Source: TRAIL Research School, 1996

Barge Hub Terminal

Another idea, which is now seriously considered, is the development of a so called Barge Hub Terminal (BHT) in or near the port of Rotterdam. The concept assumes that barge hinterland services are offered via this intermediate terminal: it functions as a collection/distribution point for (barge) containers transported to and from the hinterland.

The aim is to reduce the number of calls in the port of Rotterdam, and there are several different types of possible operations (see Pielage *et al.*, 2007). The barges could for instance only unload the small call sizes at the BHT and then continue to the port (with a reduced number of calls), or at the other end of the spectrum they could unload all containers at the BHT leaving the distribution in the port to other barges. Figure 6.6 shows the operations in this latter process. For the return flow, from the port to the hinterland, the BHT could of course perform the same collection/distribution or exchange function. Figure 6.7 gives an artist impression of such a barge hub terminal.

Figure 6.6 A barge hub terminal to exchange containers between hinterland transport vessels and port collection-distribution transport vessels



Source: Pielage *et al.*, 2007

The Barge Hub Terminal appears to be an economically and environmentally sustainable way to respond to increasing growth of hinterland transport as the following benefits of this network are envisaged:

Performance improvement of barge hinterland operations:

- improvement of the hinterland vessel turnaround time (higher productivity), because of a reduction of the number of calls in the port;
- improvement of the cost and reliability performance of barge hinterland services.

More efficient performance of marine terminals:

- a higher crane/quay productivity, because the average productivity of handling containers in large call sizes is higher;
- a better utilisation of space at marine terminals as the dwell time of containers at marine terminals can be reduced if the barge hub terminal can also facilitate a storage function for (empty) containers.

Improvement of port accessibility to and from the hinterland:

- A barge hub terminal may also act as an ‘extended gate’ for container trucks operating in long-distance hinterland transport. By dropping and picking up their containers at the barge hub terminal instead of visiting the marine terminals trucker may avoid road congestion that particularly occurs in the port terminal areas. Hence they also increase their productivity.
- By reducing the number of calls barges make in the port of Rotterdam, barge traffic and required lay-by berths will also be reduced.

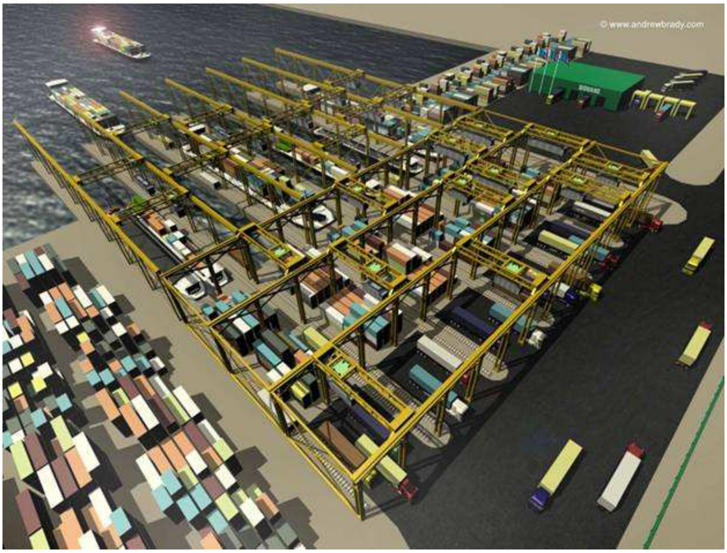
Sustainable environmental and social benefits:

- In its role as ‘extended gate’ for container trucks the barge hub network can contribute to:
- a reduction of traffic congestion in the port and at roads to the marine terminals;
- lower truck fuel consumption;
- air quality improvement (substitution of road kilometres by barge kilometres).

Development of possible new markets

- A barge hub terminal can enable new container barge services between inland terminals for freight that has no relationship with the seaport, i.e. continental cargo. Bundling maritime and continental container freight on vessels sailing to the hub enables services between pairs of inland terminals that have insufficient transport volume to start a direct (shuttle) service.

Figure 6.7 Artist impression of a barge hub terminal to streamline hinterland transport of the port of Rotterdam



Source: Port Authority Rotterdam

Further research into the feasibility of this BHT-concept is needed. The different type of barge operations (including the type of vessels to be used) should be further analysed as well as the (distribution of) costs and savings for the many parties involved. In particular the terminal design and location should be considered in more detail as the handling costs at the BHT are a crucial factor in the cost-benefit calculations.

6.4.2 Barge handling in the capillaries of the waterway network

In order to increase the potential market for container barge transport it can be useful to expand the number of locations to get access to barge services, in particular in the capillaries of the waterway network, i.e. the small waterways. The opportunities to develop container barge transport on these waterways are still highly overlooked, in particular if the cargo flows are small. These waterways impose restrictions on the possible size of vessels and moreover if the volumes are small the handling costs per unit will often be too high to operate a conventional inland barge terminal.

During the last decade several ideas have been launched with varying success to make barge transport attractive for these small flows. These ideas concern innovations in both vessels[20] and terminals.

Low-cost inland terminal

In 1998, a study was conducted on a barge terminal design that aimed to improve the cost performance of intermodal barge transport for small (continental) transport flows and hence would contribute to a better use of small waterways (Van den Wall Bake, 1998). This design focused on low-cost, small-scale operations (Figure 6.8) and included:

- An unmanned, self service terminal at which the shipping crew performs crane operations and terminal transport (to reduce operational costs);
- A light weight crane;
- Inexpensive quay facilities and shore protection;
- Stacking on wheels – decoupling of terminal processes and truck visits;
- An ability to be scalable for larger transport volumes (introduction of terminal staff, reorganization of terminal processes).

Total investment costs of this terminal were estimated at 50% of the costs of a conventional terminal. This cost saving provides a favourable condition for developing competitive barge transport services. The feasibility study of this terminal concept was promising. Serious plans for a pilot existed, but the promised co finance of the government did not come through, and the private-sector investors retreated.

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[20] In addition to self (un)loading vessels, for instance a new type of vessel was introduced (Neokemp), that among other innovations (i.e. speed, manoeuvrability and cockpit location) could increase its loading capacity compared to conventional vessels having the same size through a better use of space. Furthermore special container push barges have been designed and built (e.g. in France and The Netherlands) to maximize load capacity on very specific small waterway routes.

Figure 6.8 Artist impression of a low-cost inland terminal

Source: Van den Wall Bake, 1998

Self(un)loading vessels

As an alternative for this low cost terminal concept the idea of self(un)loading vessels got serious interest. Self(un)loading vessels offer a high level of flexibility regarding possible locations for loading and unloading cargo, independent of transport volumes. They are eminently suitable for small-scale and dispersed container transport. Several studies into self(un)loading vessels have been conducted involving different technical designs (Savenije, 1997; Willems BV, 1998). Self(un)loading vessels proved technically feasible, but not economically feasible. The crane on board would consume too much space and restrict an already limited loading capacity of the vessel. In other words, the vessel size appeared to be a bottleneck in those designs of the late 1990s.

In 2005 this idea of self(un)loading vessels has been taken up again, motivated by road congestion in the region of the port of Amsterdam in picking up and delivering containers for the local industry. Currently a successful pilot project is running in which a self(un)loading vessel performs the pick ups and deliveries in this region. However, the dimensions of this vessel (86 x 11.55 m) are close to the size of commonly used container barges and it has a slot capacity of 144 TEU (Figure 6.9). Its handling productivity (18 containers/hour) is not much lower than for a conventional inland terminal (about 25 containers/hour). It functions as a regional collection/distribution system: the services make the connection to *deep-sea* lines in Amsterdam. At the moment it also sails on to *deep-sea* terminals in Rotterdam and Antwerp. As such it still combines pure collection/distribution and line service characteristics. In the project the focus is now on expanding and improving a number of pick up and delivery points (e.g. jetties) in order to increase the accessibility of more companies and business areas.

This vessel can possibly pave the way for a stronger position of barge transport in dispersed flows on short distance.

Figure 6.9 A self(un)loading container vessel in The Netherlands

Source: www.mercurius-group.nl.

6.4.3 Barge handling in more complex service networks

As shown, the introduction of a new type of services, i.e. trunk-feeder services, has enabled to open up a new market for container barge hinterland transport, i.e. some tributaries of the Rhine, in a cost efficient and qualitatively competitive way. A next step in network development could be the introduction of a hub-and-spoke (H&S) network to capture other new geographical markets, such as for instance the market for continental cargo. In a H&S network origins and destinations are connected with star-shaped transport links (spokes) via one centrally located point, i.e. a terminal (hub). Due to its multi-directed (star-shaped) structure it would be pre-eminently suitable to enhance the geographical coverage of transport services. Moreover, owing to its typical features the H&S network is also very suited to implement new services between origin-destination pairs for which the transport flow is too small to run a direct (point-to-point) barge service. Both these characteristics are therefore highly supportive to enable market expansion.

The additional handlings in the hub result in additional costs, but these costs may be compensated by the improved cost performance on the network as a whole. Implementation of point-to-point services between the hub and spoke terminals can keep the turnaround time of a vessel relatively small in order to make the vessel most productive, i.e. achieving economies of density, and the vessel size can be fully adapted to the waterway dimensions of the specific spoke, i.e. maximizing economies of scale.

A critical factor in realizing such a service network is the organization of the container exchange in the hub. It will be a challenge to exchange containers efficiently, reliably and fast, taking into consideration that also the sailing schedules of vessels from different spokes should be tuned in order to offer acceptable transit times. This is a real challenge because transhipment in barge transport is faced with some constraints that can endanger a fast and cheap exchange of containers.

Loading/unloading times of barges are relatively long. The main explanation for this is the large capacity of vessels, compared to for instance the capacity of trains. It takes much time to unload and load a vessel completely, about 6 to 8 hours for a vessel that has a capacity of 208 TEU. Of course, the time consumption will depend on the number of units to be exchanged, the available crane capacity and possible waiting times. However, partial exchange may result into other kind of problems. The time consumption of exchanging containers between vessels may have a negative effect on the total transit time within the transport chain.

The difficulties of simultaneous exchanges. The exchange process requires vertical container handling operations by cranes. Direct exchange of containers between vessels is difficult to achieve, unless appropriate cranes are available and time schedules of vessels are tuned. If these conditions cannot be met, temporary quay stacking and additional handlings are needed. This will increase the transit time and costs within the transport chain. It is conceivable that containers can be regrouped horizontally through the exchange of push barges, making the exchange process easier. However, this assumes that containers can only be regrouped batch wise in rather large batches, which make the hub-and-spoke system less flexible.

The importance of the loading/unloading order. Much more than for trains, the sequence of loading/unloading and the positioning of containers is critical and complex for vessels. Loading/unloading operations have to take into account vessel stability and the containers' position aboard in relation to its destination to avoid digging up containers, which results in additional handlings. A good load planning may help to overcome this problem.

Whether these circumstances, and the time and money costs involved, are a real barrier or not depends on the specific networks considered: costs savings on the network level (for instance by economies of scale) may overcompensate the additional costs resulting from exchanging containers between barges.

The experiences with the trunk line-feeder services show that barge-barge networks can have a rationale. However, since exchange of containers in these services is between two vessels only, this is not a very complex process. However, the containers are usually not transhipped board-to-board, but are temporary stacked at the quay.

In terms of physical design such a hub terminal could much resemble to the one that is currently under study for the port of Rotterdam (see Figure 6.7).

6.5 Conclusions

There is a big challenge to increase the market share of container barge transport. On the one hand in its role as a hinterland transport mode in contributing to keep the seaports accessible. On the other hand to increase its geographical scope, i.e. the development of transport services between continental origins and destinations. This assumes barge services that can compete with road transport by improving the efficiency in existing barge service networks and developing new types of service networks to capture new markets.

The role of terminals in realizing these objectives may not be overlooked. The relatively large share of terminal costs in the total barge transport chain makes terminal handling a major cost frontier. On the other hand the possibilities to operate certain barge service networks are strongly determined by the performance of terminals in these networks. New terminal and handling concepts can therefore contribute to making container barge transport more attractive. Different terminal and handling concepts are needed, in which the size of transport flows – large or small volumes – is an important distinguishing factor. To handle large volumes the focus should be on concepts that can reduce the time for loading/unloading. This holds in particular in the seaport, but also for inland terminals where volumes are growing and more and larger vessels need to be handled. In its possible role of being a hub the sorting function in an inland terminal becomes an additional requirement. Controlling the transhipment costs in these large-scale terminals is obviously very important, but this is even more the case for terminal and handling facilities aimed at handling small volumes. In capturing small volumes the transhipment costs must be kept low. Here low cost inland terminals and self (un)loading vessels can play a role to further open the market for container barge transport.

This paper has demonstrated promising directions for new terminal and handling concepts and discussed some concrete study designs. To bring these concepts closer to adoption they need to be further developed and/or analyzed for the specific business cases. Exploring the willingness of actors to invest in these innovations will also be part of this process.

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7 Integrated centres for the transshipment, storage, collection and distribution of goods: A survey of the possibilities for a high-quality intermodal transport concept

Konings, J.W. (1996) Integrated centres for the transhipment, storage, collection and distribution of goods. A survey of the possibilities for a high quality intermodal transport concept, in: *Transport Policy* 3 (1/2), pp. 3 – 11. Copyright © Elsevier Science Ltd.

Abstract

In many circumstances intermodal transport is not competitive to direct road haulage. Intermodal transport is often less cost-effective, more time-consuming and less reliable than road transport. The necessary handling and the initial and final road section in an intermodal transport chain play an important role in this respect. Cost savings and quality improvements in the handling systems at container terminals as well as in the initial and final road section are therefore vital instruments for enhancing the competitiveness of intermodal transport. The concept of 'integrated centres for the transhipment, storage, collection and distribution of goods', presented in this article, integrates these policy instruments. The integrated centre is characterized by the spatial and functional integration of container handling, storage plus businesses having intensive container transport. The key element of the centre is the centre's own internal transport system. This paper outlines where, and under what conditions, these integrated centres could be best developed. Finally, the possibilities for developing such a centre at the Rotterdam Maasvlakte area are more fully discussed.

7.1 Introduction

Numerous cargo handlers are on the lookout for new transport concepts to enable them to meet the steadily rising demands being made by their clients. Increasingly, clients want their goods delivered faster, cheaper, more conveniently and just-in-time. Many are also of the opinion that the road network will be increasingly unable to meet such demanding quality criteria. Costly environmental protection measures and worsening congestion problems are expected to seriously compromise road haulage activities. Road transport will become considerably more expensive, more time-consuming and, all in all, less attractive than it is now. Many therefore see a shift to barge and rail transport, as part of a intermodal transport chain, as the answer. However, intermodal transport systems suffer a number of limitations, and in the face of worsening road transport conditions they offer no guarantee of success.

This article presents a transport logistics concept which anticipates the shortcomings of current and future intermodal transport and which is intended to safeguard the quality of the most strategic transport chains utilized by the haulage industry. It will explain where, and under what conditions, the concept of 'Integrated centres for the transhipment, storage, collection and distribution of goods' can be applied. We will begin with a brief outline of the most important shortcomings of existing intermodal transport.

7.2 The shortcomings of current intermodal transport

As we have said, intermodal transport suffers a number of important shortcomings. Some are already evident, and others will become more pressing in the future, if radical changes do not occur. To start with, intermodal transport often cannot compete in ordinary cost terms with direct road haulage. In themselves, rail and barge transport are often competitive, but their advantage is frequently cancelled out by the added costs of the necessary handling and the initial and final road transport sections. These additional costs are relatively high, particularly over shorter distances (Figure 7.1).[21] As road transport prices rise, so will these additional costs, and combined transport will suffer accordingly, unless initial and final road transport can be exempted from the increasing prices in road transport. The profound effect that these additional costs have on the total cost of intermodal transport means that it is in this area, in particular, that cost-saving measures must be sought.[22]

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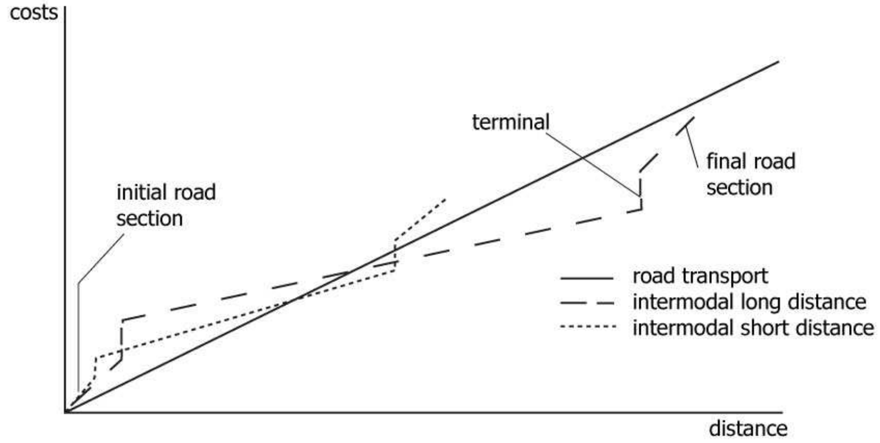
[21] Maritime combined transport, however, can compete more easily with direct road transport than can continental combined transport, as in this case the chain starts at a sea terminal, thereby omitting the initial road transport costs to the terminal itself.

[22] Reductions in rail and barge transport costs can nevertheless still be an important source of cost savings (see also Knight Wendling Consulting BV, 1995).

Figure 7.1 Cost structure of unimodal road haulage versus multimodal transport



Source: Rutten, 1995

Secondly, reliability and transit times in intermodal transport do not always come up to desired standards. This can be attributed to the existence of extra links in the chain of intermodal transport. The rise of shuttle services may have eliminated some of these linking problems, and thereby improved the quality of transport on the main route (rail or barge), but the junctions where one mode of transport has to adapt to another invariably exist.[23] The mutual attunement of these different transport modes is of vital importance, and the handling qualities at these junctions will increasingly be decisive for the reliability and transit times of combined transport chains in the future, especially with rising payloads.

Larger payloads in intermodal transport will not only increase the demands made on handling technologies at terminals, but will also make initial and final road transport arrangements increasingly critical. The growth of intermodal transport, after all, entails the growth of road transport activity around terminals (see Figure 7.2). This growth can threaten the accessibility of the terminal itself: a situation which can already be seen in Rotterdam's busy harbour area, amongst others, and which is predicted to seriously affect a number of other ports in the future.[24] This means that intermodal transport might, in a sense, actually fall victim to its own success, and finds itself unable to meet market expectations.

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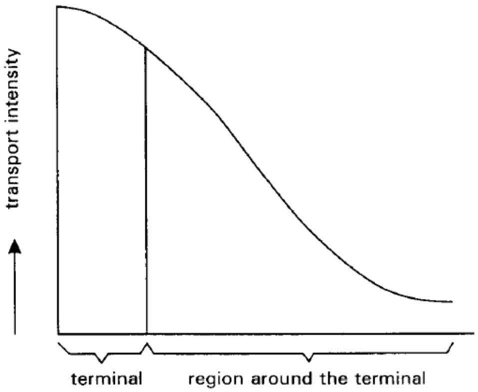
[23] Except where a train or barge can be loaded and unloaded within the premises of the business itself.

[24] In this connection, Rutten (1995) points to the new terminal at Hamburg-Billwerder, designed to be able to handle 400,000 standard units by the year 2000. Though this capacity can effectively replace 250,000 long-haul road journeys, it also means that 500,000 (!) freight transfers take place on roads to and from the terminal.

Figure 7.2 Transport intensity in the vicinity of a terminal



For these reasons, cost savings and quality improvements in handling systems and in initial and final road transport arrangements will be an important starting point for new developments. Up to now, research efforts and field initiatives have been directed primarily towards technical improvements in handling techniques (Krupp Fordertechnik, 1993; Noel, 1993; Mannesmann, 1995; Wijnolst *et al.*, 1995; Huijsman *et al.*, 1995) or towards the more efficient organization of initial and final road transport (see Venemans, 1994; Brugge *et al.*, 1994). Ideas for adopting a more integrated approach are less developed as yet.

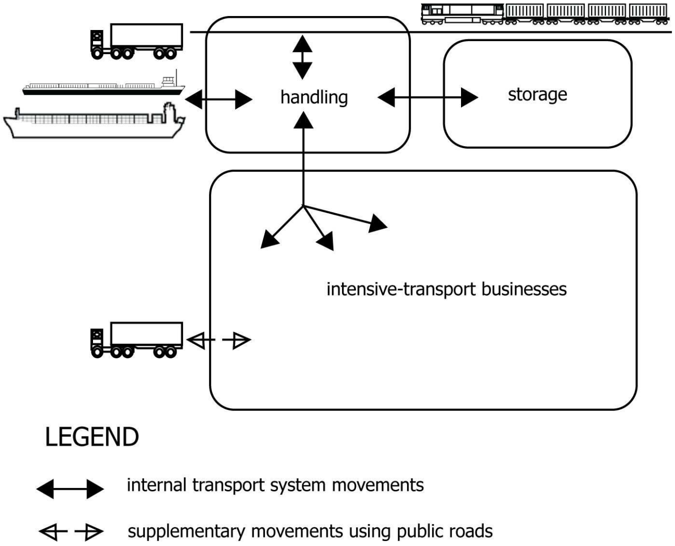
7.3 The concept of integrated centres for the transhipment, storage, collection and distribution of goods

A freight transport concept which aims to meet the shortcomings described above is the concept of integrated centres for the Transhipment, Storage, Collection and Distribution of goods (TSCD) (see also Kreutzberger, 1992). Just as in intermodal transport, it assumes payloads with a standardized, unit form (containers for the most part, but also swap bodies and the like).

The TSCD concept involves the spatial and functional integration of container handling, storage, plus businesses having intensive container transport, within a specially-designed area, a so-called TSCD site or TSCD centre. At this site the terminal may act as a key element within a cargo traffic centre. The elements of the TSCD centre are linked to the centre's own internal transport system (Figure 7.3). This internal transport system collects the containers from the private companies established at the site and takes them to the terminal, and vice versa. The internal transport system also fulfils other functions; it moves containers from one terminal to another (in instances where the junction is multimodal) and also moves containers between terminals and storage areas (stacks). Extending the employment of such an internal transport system to include handling processes as well as collection and distribution functions can make the centre's entire handling system markedly more efficient.

The internal transport system has to move containers cheaply, quickly, reliably and flexibly, so that the price and quality of initial and final transport can improve that offered by a conventional road haulage system. The descriptions of these tasks should encourage us to think about transport and handling techniques in which automation plays a role. The scale of transport and handling activities, the fact that standard units are employed, added to the desire to keep handling and transport costs as low as possible, all point to the possibility of automation.

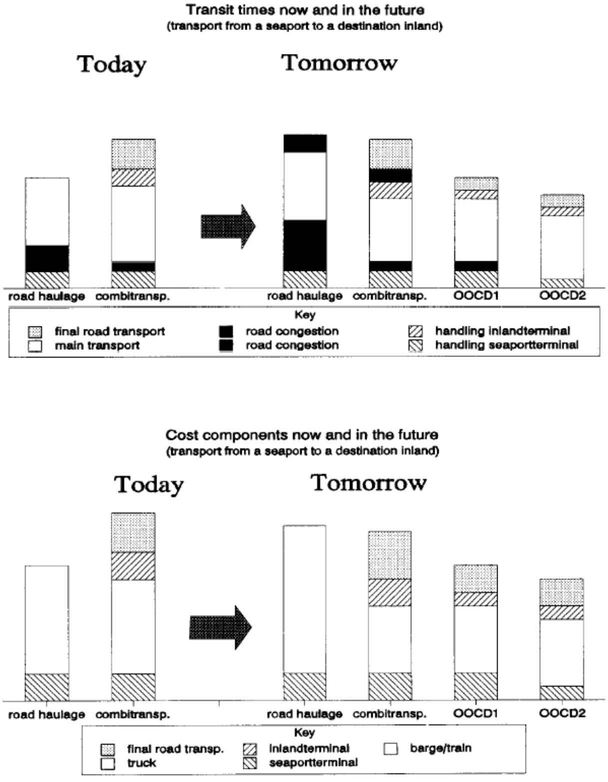
Figure 7.3 The elements of an TSCD centre



The special value of the TSCD concept arises along two dimensions. In the first place, siting a business in the immediate vicinity of a terminal obviously reduces the initial and final transport distances involved (the concept's spatial dimension). This has beneficial effects on costs, transit times, and the reliability of intermodal transport techniques. Secondly, an internal transport system to be used for the collection and distribution of containers to the companies on the site and well tuned to the transport and handling techniques at the terminal, makes a more efficient initial and final transport phase possible (the concept's functional dimension). The price and the quality of the entire intermodal transport chain are thereby further improved. These two dimensions are not mutually independent; one can strengthen the other. The agglomeration of businesses very near the terminal will create a support base for intermodal transport services. On the other hand the internal transport system can enhance the overall attractiveness of intermodal transport itself and therefore of the TSCD site as a place of business.
The combination of the two dimensions ensures that transport via a TSCD-chain is cheaper, faster and more reliable than conventional intermodal transport or direct road haulage. Efficiency will be further enhanced by a network of TSCD centres, that is to say, if both ends of the transport chain employ the TSCD concept. Figure 7.4 shows this in diagrammatic form.

Besides its purely commercial interest, the TSCD concept also brings clear social benefits. The reduction of road haulage, arising partly from shorter initial and final transport runs and partly from an alternative for road transport[25], is of benefit not only to other road users but also to the environment.

Figure 7.4 The TSCD concept as response to declining quality in the transport chain



*OOCD*1: *OOCD* facilities at one end of the transport chain, eg the inland terminal
*OOCD*2: *OOCD* facilities at both ends of the transport chain, eg the inland terminal and the seaport terminal

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[25] The substitution effects are twofold, involving on the one hand initial and final road transportation and on the other hand direct road haulage. In the latter case, intermodal transport would increasingly replace long-haul trucking.

7.4 Potential businesses for a TSCD centre

The TSCD concept is directed towards those businesses which make the highest demands of their goods transport facilities: in other words, businesses for which the price and quality of transport is of crucial importance for the success of the chosen distribution strategy. These strict demands are to be found primarily in those business sectors increasingly opting for global production together with centralized distribution systems. Since their products are manufactured worldwide and then stored at, and distributed from, just one (or a very few) location(s), their logistic chains are somewhat stretched, and their transport programme is consequently subjected to higher demands. Supplies must arrive cheaply and reliably, and deliveries must reach their destinations quickly and reliably. These, in fact, are the transport features which the central European distribution concept has to thank for its existence.

European (and other) distribution centres have also demonstrably confirmed the importance of these factors in their location strategies. Such businesses are showing increasing interest in handling locations which are well situated from a market-geographical point of view and which can offer the quality of handling that today's businesses demand. Various distribution centres have already opted for sites close to an established terminal, in the expectation that this will cover the risk of declining in transport chain quality due to increasing road traffic congestion.

Such distribution centres need not be the only prospective clients for a TSCD site, but it is clear that businesses like these, with high transport intensity, container use and a 'footloose' character, are ideally suited to a TSCD centre (see also Konings, 1996).

7.5 Potential locations for TSCD centres

Potential TSCD centres would include, in the first instance, those terminals at which several businesses of a given type already share a site: a so-called 'distripark'. The presence of such parks at terminals is no longer a new phenomenon, although most European distriparks are still to be found near important motorway interchanges (St Quintin, 1993). Since terminal operators have perceived that shippers and transporters appreciate supplementary terminal services which can raise the added value of their product distribution services, the number of such services at and near terminals has been growing. This started with the offer of fairly simple container services (empty depots, container repairs, etc.) and has expanded steadily, moving into various forms of physical distribution activity carried out on neighbouring business sites.

In Germany, this has resulted in the emergence of Güterverkehrcentren; these include intermodal handling facilities and are railway freight handling locations for the combining of part-loads from regional distribution centres of the post offices and from other transport, distribution and logistics companies (Kreutzberger, 1994). Similar freight handling centres are also emerging in other countries ('Freight Villages' in the UK, 'Interporti' in Italy: NEA *et al.*, 1992). A number of such rail-terminal-linked business sites or distriparks have also arisen in the Netherlands (Eem/Waalhaven and Botlek in Rotterdam and the Venlo Trade Port in Venlo, amongst others).

Given their modern approach, and in particular the degree to which spatial integration already characterizes the design of the above-mentioned centres, these could well be successfully developed as full TSCD centres. However, as long as traffic to and from these terminals is not on a scale for which congestion would form a real threat, it is justifiable to use less advanced vehicles for distripark-related transport purposes. Given the limited throughput volumes, the anticipated cost and quality improvements in initial and final transport that an advanced (automated) transport system would produce, would not, as yet, be achieved. In other words, at smaller centres, simpler solutions would be more effective. A good example of this is the Venlo Trade Port in the Netherlands, at which about 50,000 units are handled per year. For the transport of containers between the road/rail terminal and the adjoining logistics park, the company has opted to supplement their trucks with a number of terminal tractors. These are more flexible than the trucks and actually provide the company with costs savings of about 50%.[26]

The areas where a TSCD centre really comes into its own are those areas in which very large handling volumes can be expected; those terminals, for instance, which besides functioning as freight handling hubs for various transport modes, seek an important role as local and regional distribution centres. Though this also applies to inland terminals, it is seaport terminals which fit this bill at the moment.

7.6 A closer look at the Rotterdam Maasvlakte

Rotterdam has some of the most forward-looking plans of any European seaport. An ambitious expansion plan, Delta 2000-8, was set up in 1990 as part of a scheme to develop container activities in the Maasvlakte area. The plan included a number of infrastructure projects which could mean that the freight handling centre at Maasvlakte could eventually become a ‘super-hub’ for all transport modes (a ‘Delta Mega Hub Center’) whose handling turnover could rise from today’s 1.4 million containers to 3.6 million in 2010.[27]

On the seaward side, the capacity of the two existing terminals (the Delta Multi User Terminal and the Sea-Land Terminal) would be enlarged by the addition of eight new container terminals which, following the Sea-Land terminal concept, would be highly automated. Internal transport at these terminals would be carried out wherever possible using robots such as Automated Guided Vehicles (AGVs) and Automated Stacking Cranes (ASCs).

Volume growth will naturally affect not only seaward side but also landside activities. Rail container transport is foreseen to rise to 450,000 containers; barge container transport to 600,000 by 2010; and road container transport between terminal and hinterland to 950,000. Intermodal handling points are envisaged for barge transport (a Barge Service Center) and for rail transport (a Rail Service Centre); new facilities are also envisaged for truck handling (a Truck Service Centre). All in all, these terminal facilities will cover 180 hectares, not including an ‘empty depot’ (MTY). The Delta 2000-8 plan finally includes a large-scale distripark (123 hectares in all) directly adjoining these terminals[28] (Figure 7.5). Enormous

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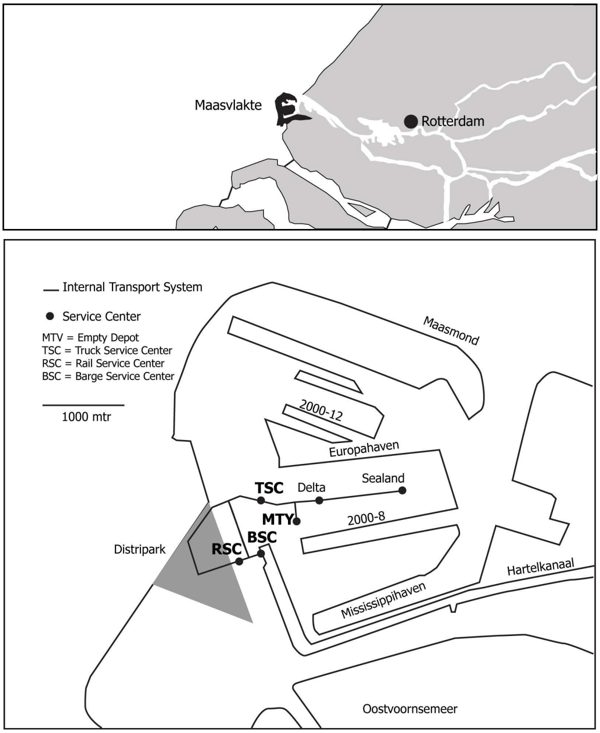
[26] These savings are generated by the fact that the terminal chassis is cheaper than a conventional truck chassis, and because the process is shorter than with final transport by truck.

[27] By 2020, 5-9 million containers per year are envisaged, depending on levels of economic growth and the development of Rotterdam’s competitive position (Incomaas, 1994). This growth scenario does involve investment in a new generation of sea terminals in which cargo ships can be handled from both sides simultaneously. This investment plan forms part of the container project Delta 2012 which should be seen as the follow-up to Delta 2000-8.

[28] In a possible second phase, in which the Maasvlakte is enlarged seawards, the area of this distripark could be increased to a maximum of 275 hectares in all.

volumes will be transported not just to and from such a mega-terminal but also between its numerous facilities. It is widely expected that in the long term, conventional transport modes and information technologies will be unable to meet these demands, and innovative freight transport and handling systems will have to be installed. This is certainly true for interterminal transport, and probably also for transport between terminals and distripark.

Figure 7.5 Positioning and layout of the Delta Mega Hub Centre



Despite the proximity of the various terminals (sea, rail and barge), it is by no means certain that the distripark businesses can continue to guarantee an ideal supply of transport as long as they carry on using trucks: by 2010 this would mean at least 100,000 truck movements per year between the sea terminals and the distripark alone. Then there are the movements between the distripark and the empty depot, the distripark and the hinterland, and of course the much greater number of containers going directly to or coming from outside the Maasvlakte area by truck (950,000). The inevitable consequence of this enormous number of trucks will be a severe congestion problem in and around the terminals.[29] Here, too, the creation of a TSCD centre is a realistic option.

7.7 What a TSCD internal transport system can and cannot do

In talking about a transport system for the on-site transport of containers, a wide variety of possibilities and techniques could be considered: road transport like systems using extended trucks (3TEU (Twenty feet Equivalent Unit) or 4TEU trucks), the terminal tractor system, the multiple trailer system, more advanced systems like the Automated Guided Vehicle (AGV) system, monorail systems, chain-driven systems, rolling roads and so on.

It is important to remember that the technical characteristics of such a system and the transport organization that it entails have to integrate with the possibilities offered by the site, its existing facilities, and the wishes and requirements of the distripark businesses and the terminal operator. With this in mind, it is self-evident that the automation of initial and final transportation is of little use when handling activities already take place using conventional, manned cranes.[30] On the other hand, far reaching automation at handling terminals – such as already exists, and is to be extended, at Maasvlakte – can be an important stimulus for giving automated systems such a role when considering new collection and distribution transport systems to and from a distripark. At Maasvlakte, an adapted AGV system could be considered, although it would be expensive. The integration of terminal handling and transport activities would probably improve the quality and cost of freight handling there, but the interfacing of an automatically guided vehicle and a distribusiness is a complicated matter (Konings, 1996). This is avoided if both container terminal and distripark are provided with a stack for loading and unloading AGVs. The interface problems are hereby circumvented, and it also allows AGVs to be more efficiently employed (Konings, 1996), but the most important disadvantage is that an extra handling move is created. Freight transport from this distristack to businesses' doors would still depend on traditional truck haulage, or perhaps a terminal tractor.

An automated transport system avoids the congestion problem and thereby improves transit times and reliability, but it is still open to question whether distripark businesses would not have to bear excessive costs for initial and final transport. The crucial factor here will be the cost/quality relationship compared to the road truck (Konings, 1996). The relatively high fixed costs (time costs) characteristics of initial and final transport by road will here become a critical cost factor. These time costs, constituted for the most part of drivers' wages, will increase as waiting times at terminals rise. Over time, then, the attractiveness and feasibility of automated transport systems can only grow.

Besides the high costs of AGVs, and its abovementioned interface problems with individual businesses, the fact that strict boundaries have to be maintained between AGV traffic and ordinary traffic is a handicap. This handicap can be partially surmounted only by making exceptional demands on the distripark's design and layout. Since automated systems have these problems, it might make sense to examine whether non-automated transport systems

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[29] The problems created by using trucks will not be limited to those businesses working at the Maasvlakte distripark, but will also affect other businesses, both in the region and further afield, using truck haulage.

[30] Venlo's approach has shown that the actual demands of distribusinesses can sometimes be satisfactorily met using relatively simple means.

could provide a satisfactory solution. Given the distripark businesses' wants and needs, a number of road-transport-like systems present themselves.

The '4TEU truck', a tractor unit with a 2-container trailer and another such trailer in tow, requires a relatively small investment; one, moreover, limited to the vehicle itself. A 4TEU truck can use ordinary distripark roads. Its speed, penetration and flexibility are only a little lower than those of an ordinary truck. Possible transport cost savings of 25% represent an attractive incentive. The limited manoeuvrability of the 4TEU is, however, a disadvantage, and one which can cause handling problems for distripark businesses. At any rate, some extra handling work would seem to be inescapable. A more fundamental objection to the 4TEU is that it represents, both literally and figuratively, only half a solution to the terminal congestion problem: after all, the number of containers moved by truck remains exactly the same.

The multi-trailer system could represent an attractive and more effective solution. The system consists of a number of rubber-tired trailers towed by a strong, suitably adapted tractor. One of this system's most important characteristics is its capacity for variable train formation, a feature which allows its operators to make full use of scale economies and which reduces individual traffic movements at the terminal. Because more than one container (up to 10 TEU) can be moved at once, transport cost savings are possible. As far as speed, manoeuvrability and expandability are concerned, the system scores well, even compared to the conventional road truck. However, as with AGVs, multi-trailers can give rise to container loading and unloading problems for distripark businesses. Such problems could be solved by developing a de-linkable trailer system, although this would bring extra investment costs. All in all, since such a system would integrate quite readily with ordinary truck transport, requires no radical adaptations to the distripark itself, and can lower the costs of initial and final transport, it would certainly seem to be a promising candidate. Another possibility is that multi-trailers are unloaded by means of simple gantry cranes, which deliver the containers over a certain distance to the business' door. Savings here are generated by the fact that fewer trailers are required, since only the container itself is detached from the 'train'; this advantage, however, has to be set against the extra costs of the gantry cranes, and the fact that a number of adaptations have to be made to the distripark itself.

These aspects of internal transport systems are not the only considerations. For example, there are questions of available space and system safety. These aspects play a more important role when a new system is introduced into a distripark which is already partially or completely developed.

7.8 Conclusions

The TSCD concept can make an important contribution towards the strengthening of intermodal transport systems, and, as such, towards the future accessibility of individual businesses. Full implementation of the 'freight handling hub' concept, however, is not suited to every terminal, but depends on its scale and function.

The concept can be evaluated in terms of its two dimensions: on the one hand, the benefits obtained by siting businesses in the immediate vicinity of a terminal (the spatial dimension), and on the other hand, the significance of improving the efficiency of freight handling, storage and internal transport between terminal and distripark (the functional dimension).

TSCD's spatial dimension contributes in particular to the qualitative improvement of a intermodal transport chain. Physical proximity generates savings in transport time, an increasingly useful benefit wherever this avoids road haulage in congestion-prone areas. Delivery reliability is thereby also improved. The cost of initial and final road transport over a reduced distance between business and terminal can also fall, although kilometre costs generally weigh much less heavily than time costs.

Several distribution centres have already opted for near-terminal locations for these reasons alone, though for many the financial advantages of such a location are, as yet, insufficient. This is primarily due to a strongly road-oriented view of transport, which can partly be the result of business practice itself,[31] but it is also due to the mediocre quality of present intermodal transport systems. In anticipation of future developments, however (road congestion and road haulage taxes), the popularity of near-terminal locations is already clearly growing. The development of distriparks with multimodal facilities is therefore going to proceed apace.

These distriparks could also create an increased support base for smaller terminals, and even new terminals, which would be a mutually sustaining process. Business accessibility for the terminal would increase the attractiveness of – and therefore the demand for – an intermodal transport system; a more attractive range of intermodal transport facilities would attract new businesses.

The TSCD's functional dimension will prove its worth most clearly at large freight distribution/handling terminals threatened by a potential congestion problem. The integration which an internal transport system provides between terminal freight handling processes and initial and final road haulage, however, should not stop at congestion avoidance, but should be carried through so as to produce savings in transport and handling costs. Where freight volumes are large enough, the automation of transport and handling processes can certainly be considered, but such automation is still expensive and risky. At this moment there are no terminals at which advanced systems have been installed for initial and final transport purposes. The Delta Mega Hub Center at the Maasvlakte site at Rotterdam could play a pioneering role in this respect.

The solution proposed by the TSCD concept to the initial and final transport problem is very specific and will apply in the first instance to a somewhat limited number of businesses. Other, more general strategies may also be pursued. Improved information facilities (such as preregistration systems at terminals and information exchange between road users to reduce the number of empty truck movements) also represent important improvements in the price and quality of initial and final transport; peak freight loads on terminals, and the ensuing congestion, can also be reduced when containers can be delivered at night. Indeed, small-scale experiments are already being carried out in these areas.

In addition, new handling systems, such as those developed by Krupp Fordertechnik (1993), Noell (1993) and Mannesmann (1995) can serve to encourage progress in the quality of intermodal transport systems.

Lastly, the optimalization of initial and final transport, as perceived by the TSCD concept, is pointless unless main line transport provides high levels of cost effectiveness, time-effectiveness and reliability. Fast, cheap and (especially) reliable main line transport services

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[31] Outgoing goods traffic is often characterized by its intricacy: decontainered part-loads that businesses prefer to deliver by road. However, stockpiling principles could enable at least part of this outgoing goods traffic to be delivered using combined transport techniques.

along inland waterways and railways are vital preconditions to the success of TSCD as a high-quality intermodal transport concept.

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8 The competitiveness of intermodal transport in spatial perspective: what is the scope of intermodal transport?

Konings, R., Y. Bontekoning and C. Maat (2006) De concurrentiekracht van intermodal vervoer in ruimtelijk perspectief: intermodal op welke schaal?, in: M. Despontin & C. Macharis (eds), Mobiliteit en (groot)stedenbeleid, *27ste Vlaams Wetenschappelijk Economisch Congres*, Brussel, pp 181 – 205. Copyright © VUBPRESS.

Abstract

Intermodal transport has acquired a market position in specific submarkets (in hinterland transport in particular), but in view of increasing problems caused by the current dominant transport mode, road transport, a larger market share is desirable and necessary. In order to improve the competitiveness of intermodal transport in both current and new markets a cost reduction and quality improvement of intermodal transport services is needed. By definition transport networks have a spatial dimension, but the spatial structure of these networks has a strong influence on the viability of intermodal transport. This relates to the accessibility of intermodal infrastructure (rail lines, waterways, terminals), but also addresses the need for a minimum transport volume required to offer attractive and profitable intermodal transport services. This touches to the central question dealt with in this paper: at which geographical scale intermodal transport services can be offered? Related issues here are the optimal size of the service area of a terminal, possible performance improvements in pre- and post truck haulage and the optimal size of intermodal terminals. In this paper these topics are discussed and empirically illustrated for intermodal rail and barge transport in Belgium. It is shown that the geographical scale for profitable intermodal services is, in addition to the performance of barge or rail hauls and terminals, also strongly determined by the performance of pre- and

post truck haulage. The paper concludes that spatial planning should get more emphasis in policies to support the competitiveness of intermodal transport.

8.1 Introduction

The quality of freight transport is increasingly under pressure. To a large extent this is caused by a continuous general growth of transport and the dominant role of the road transport mode in freight transport, while the development of infrastructural capacity lagged behind transport growth.

The number of passenger kilometres performed annually in Belgium by the three major transport modes (car, public transport by bus, tram, subway and domestic train transport) increased by 115% from 1970 to 2000. The number of tonne-kilometres performed by the major freight transport modes (road, rail and barge transport) grew in the same period with approximately 90%. The increase in mobility in Belgium (and also in other European countries) has been predominantly accommodated by road transport, as shown for the freight transport sector in Table 8.1. The market share of road transport has gradually increased to more than 70% since the year 2000.

Table 8.1 Modal split in inland freight transport in Belgium (% of tonne-kilometres), 1970 - 2000

	1970	1980	1990	2000
Barge	23.9	19.3	14.0	13.7
Rail	28.1	26.4	21.6	14.4
Road	48.0	54.4	64.4	71.9
Total	100	100	100	100

Source: http://aps.vlaanderen.be/statistiek/publicaties/pdf/omgeving/Hfdst_9.pdf

The strong growth of freight transport is expected to continue: over the period 1998 to 2010 an increase of 40% is expected. From 1995 to 2020 an increase of 50 to 70% is estimated (FEBIAC, 2000). Such a strong increase will further endanger the quality of freight transport, in particular if this growth will predominantly be accommodated by road transport. As a consequence the congestion on the roads will increase, and as a result the transport reliability and the productivity of transport companies decrease, because they are faced with more unproductive hours of vehicles. Moreover, the accessibility of economic centres may deteriorate and the negative impacts of road transport on the natural environment and liveability will become more manifest.

In order to anticipate this future perspective transport policies are needed which are aimed at a better utilization of the capacity of the roads, but also to seize opportunities to shift cargo from road to other transport modes. The development of intermodal transport, i.e. the movement of goods in one and the same load unit (containers, swapbodies or trailers) by successive modes of transport without handling the goods themselves when changing modes, can support such a modal shift policy. In this setting this paper discusses the growth potential of intermodal freight transport.

Intermodal transport plays a respectable role in Belgium yet. This holds in particular for intermodal barge transport. Its striking position is not only reflected by large volumes that are transported, but also its rapid development in a relatively short time. In addition to transport containers on the Rhine river (650,000 TEU in 2004) and container feeder traffic between

Antwerp and Rotterdam (950,000 TEU in 2004), numerous hinterland services have been developed between Antwerp and inland terminals in Belgium, as well as from Zeebrugge to Belgium inland terminals. The total volume of this domestic barge hinterland transport has grown spectacularly since 1998 from 60,000 TEU to 450,000 TEU in 2005. The container barge transport sector has developed itself into a mature mode for hinterland transport of containers. Furthermore, intermodal rail transport also plays a significant role in container hinterland transport. In 2004, the container volume that was transported by rail in the hinterland transport of Antwerp amounted 500,000 TEU. The market share of intermodal transport in the hinterland transport of Antwerp was 40%, of which 32% was intermodal barge transport and 8% intermodal rail transport. Hence, road transport, having the largest share (60%), indeed also has a dominant position in container transport. If we exclude the barge transport volume that results from feeder traffic between the ports of Antwerp and Rotterdam, the market share of road even exceeds 70%.

In order to further increase the market share of intermodal transport in the existing markets (in particularly hinterland transport) an improvement of its transport efficiency is needed, which enables to enlarge the market scope of intermodal transport. In addition to the hinterland transport market there is the challenge to open up markets, in which intermodal transport is not significantly present yet. As regards intermodal barge transport this is the market for continental freight transport, both in domestic and international transport relations. The main challenge for rail transport is to achieve a stronger market position in the domestic transport market, i.e. in transport on shorter distances. The common challenge of both types of intermodal transport, however, is to accomplish a greater market penetration.

To support these goals, existing intermodal network structures must be improved and new concepts for intermodal transport must be developed. From this perspective we discuss here a number of clues and options to improve the competitiveness of intermodal transport to road-only transport. In this discussion we will concentrate at the spatial dimension of intermodal transport, that is to say, the impact of strategies on the market scope of intermodal transport. The paper starts with the outline of a theoretical analytical framework, from which the opportunities to improve the competitiveness of intermodal transport can be derived (section 8.2). Next, these opportunities are elaborated and empirically illustrated (section 8.3). The paper ends with the major conclusions (section 8.4).

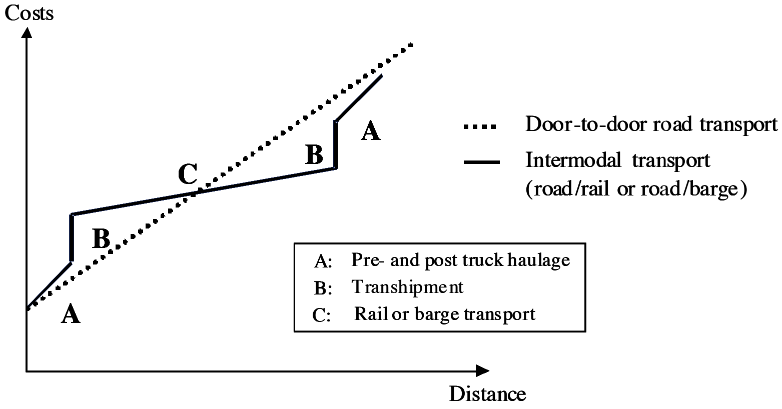
8.2 Theoretical framework for a competition analysis

Figure 8.1 shows a simple diagram of the cost structure of road-only transport and intermodal transport. The costs of road transport can be assumed proportional to the distance. The costs per TEU-kilometre for barge and rail transport are generally lower than for the road transport. Hence the slope of the line reflecting the barge and rail haul (C) is smaller than that for road transport. On the other hand, there are some additional costs for intermodal transport, namely the costs of transhipment (B) and pre- and post truck haulage (A). This truck haulage to and from a terminal is usually inevitable, because shippers and consignees generally have not an own rail track connection or are not located near a waterway. The costs of road transport per TEU-kilometre in pre- and post haulage trips, however, will generally be higher than in road-only transport (see the difference between the slopes in Figure 8.1), because the fixed costs of a trip on short distance put much weight on the total costs of a trip.

This cost difference can be explained by the fact that short trips relatively take more time. This means that the fixed costs of the trip – which are determined by the time spent on the trip – can be divided over fewer kilometres and hence the costs per kilometre increase.

It is clear that if only one truck haul in the intermodal chain is needed, the cost performance of intermodal transport immediately improves. This situation occurs in the seaport, where a container having an origin or destination oversea can usually be put directly on a train or barge at a seaport container terminal without a truck haul. This explains the relatively stronger competitiveness of intermodal transport in hinterland transport compared to intermodal transport in pure continental transport trips.

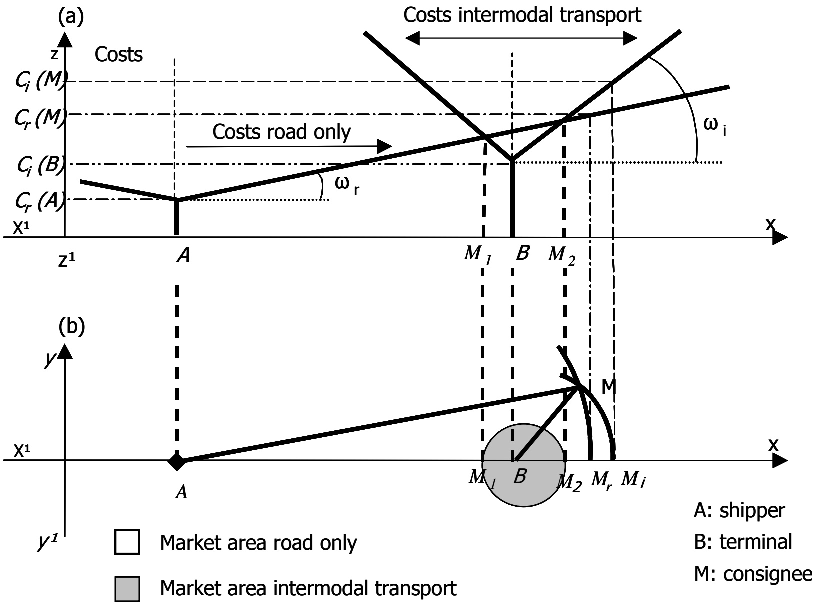
Figure 8.1 General cost structure of intermodal transport and road-only transport



Based on this simple cost diagram, the economic theory of market areas (see Palander, 1935; Hyson & Hyson, 1950), that has been elaborated for intermodal transport by Niérat (1997), offers a useful framework to analyse the competitiveness of intermodal transport and the role of truck haulage operations in particular. Based on this theory a break-even analysis can be performed, which enables to derive market areas where intermodal transport respectively road-only transport has the best market position. Figure 8.2 shows this approach. In the upper part the costs are explained. The bottom part of the figure presents the implications of the costs for the size and shape of the market area of intermodal transport. The comparison is based on a transport from A to M, which takes place directly in the road-only situation and in case of intermodal transport indirectly through a terminal located at point B. The costs for road transport are presented by a fixed part (Cr(A)) and a variable part that is proportional to the distance and can be considered as the variable costs or the kilometre costs (ω_r).

The cost curve is cone-shaped and has its minimum in the departure point A. The costs of intermodal transport are defined at point B, i.e. at the terminal where the barge or rail haul ends. At point B several costs have already occurred: possibly a truck haul operation from the shipper to the terminal, the rail or barge haul and the transhipment. However, at point B still a truck haul is needed to destination M. The costs of this truck haul can be also presented by a fixed and variable part, proportionally to the distance between B and M.

Figure 8.2 Derivation of the market scope of intermodal transport



ω_r : variable costs road-only transport

$C_r(A)$: fixed costs road-only transport

$C_r(M)$: total costs road-only transport

ω_i : variable costs drayage to consignee

$C_i(B)$: costs intermodal link AB (drayage from shipper, rail or barge haul) plus fixed costs drayage to consignee

$C_i(M)$: total costs intermodal transport

Source: Adapted from Nierat, 1997.

Now the cost curve for intermodal transport can be drawn at point B. This cost function includes:

- a fixed part which covers all costs needed to reach point B and additionally the fixed costs of haulage to consignee, Ci(B), and
- a variable part, i.e. the variable costs of haulage to the consignee (ω_i).

This curve is also cone-shaped. The intersection of both cost curves represents the break-even points of costs for road-only and intermodal transport. This approach leads to an asymmetrical circular area around point B. This circle can be considered as the market scope of intermodal transport or the service area of terminal B for shipments from A.

Since the costs for road-only and intermodal transport can be presented from point A to every random point M by respectively:

$C_r(M) = C_r(A) + \omega_r\, AM$
$C_i(M) = C_i(B) + \omega_i\, BM$

mathematically the market scope of intermodal transport can be derived by equalizing these cost function of road-only and intermodal transport:

$$C_r(M) = C_i(M) \quad \rightarrow \quad C_r(A) + \omega_r\, AM = C_i(B) + \omega_i\, BM \quad \rightarrow$$

$$\omega_r\, AM - \omega_i\, BM = C_i(B) - C_r(A) \rightarrow AM - \omega_i / \omega_r\, BM = (C_i(B) - C_r(A)) / \omega_r \rightarrow$$

$$AM - \omega\, BM = k\, AB \qquad \omega = \omega_i / \omega_r \;\text{ en }\; k = (C_i(B) - C_r(A)) / \omega_r\, AB$$

8.3 Determinants for the market scope of intermodal transport

The theoretical model in section 8.2 made clear that there are several factors that can influence the market scope of intermodal transport. We will discuss these factors here in more detail according to the three main processes that can be distinguished in the intermodal transport chain: terminal transhipment, the barge or rail haul (the intermodal service network) and pre- and post truck haulage. We will indicate the impact of some promising strategies to increase the market scope of intermodal transport.

8.3.1 Terminal handling

Transhipping load units between modalities is usually an inevitable activity in intermodal transport. The costs of transhipment vary to place (hinterland versus seaport) and transport mode (rail versus barge transport). Cost differences are caused by the use of different equipment (e.g. type of equipment or new versus second-hand equipment), but are often also the result of different circumstances (Rabobank, 2004). These circumstances may, for instance, be influenced by government subsidies, the availability of a quay (for barge transport) or rail tracks (for rail transport), but for example also by whether the ground at the terminal is in property or rented.

The relative importance of the terminal handling costs in the total intermodal chain costs depends on the total transport distance in the chain. The larger the distance, the greater the share of the barge or rail haul and consequently the share of the terminal costs decreases. In that situation terminal handling costs get a decreasing share in the total costs at point B (see Figure 8.2).

Different studies (e.g. Fonger, 1993; Rutten, 1995; Arcadis, 1999) have shown that the terminal costs generally have a relatively small share in the total chain costs. According to these studies it varies between 10% and 15%, but this not a general rule. The analyses of Macharis and Verbeke (2004) show that the share of transshipment costs in intermodal barge hinterland transport in Antwerp (Belgium) is about 30%. This can be explained by the relatively short distances at which domestic barge hinterland transport takes place.

In the nineties of the last century a lot of research and development has been carried out, which was aimed at improving the performance of terminals (see e.g. Woxenius, 1998 and Bontekoning & Kreutzberger, 1999). The aim of these studies was, in addition to achieving cost reductions, to improve the functionality of the terminal, i.e. to reduce transshipment time in order enable transport services with intermediate stops. These ideas resulted into several innovative terminal designs, but none of them has been implemented yet. Regarding rail terminals the reach stacker and gantry crane are still the most preferred transshipment techniques. For barge terminals it is the gantry crane. The use of container crane vessels, a concept focussed at accommodating small freight flows, is rather in an experimental phase so far.

The transshipment rates at a rail terminal vary between 16 and 33 Euro (Arcadis, 1999; Terminet, 2000) and at a barge terminal between 16 Euro (at an inland terminal) and 35 Euro (at a seaport terminal) (Rabobank, 2004) (see Table 8.2). However, cost calculations show that the rates sometimes are lower than the real costs. The costs of a transshipment at a rail terminal are on average between 25 and 35 Euro per load unit. These calculated costs, however, depend on the transshipment volume and the equipment that is used. A rail terminal employing a reachstacker and having an annual transhipment volume of 30,000 load units may have a cost price of €31, but if the transshipment volume would be doubled the cost price would drop to €18. At a rail terminal where 65,000 load units are handled with a gantry crane, the cost price is about €42 (Ballis & Golias, 2002, Impulse, 1997, Bontekoning, 2006, Arcadis, 1999, Rabobank 2004).

Table 8.2 Transshipment rate per load unit (LU) related to annual transshipment volume

	In hinterland: barge		In hinterland: rail			In seaport	
	Reach stacker	Gantry crane	Reach stacker		Gantry crane	Barge	Rail
Rate	€12	€16	€31 (cost price)	€18 (cost price)	€42 (cost price)	€35	€33
Handling-volume (Load Units)	50,000 LU	30,000 LU	30,000 LU	60,000 LU	65,000 LU		

Sources: Arcadis, 1999, Rabobank 2004, Ballis and Golias, 2002

From a cost perspective reachstackers are more favourable than gantry cranes. The capital costs of gantry cranes are much higher and as a result the handling costs are higher in particular if the volumes that are handled are small. However, if the handling volume increases other criteria such as handling capacity and efficient use of space become more important, which can make the gantry crane a more attractive option.

The past has shown that a reduction in transshipment costs is not so easy, but actually necessary to achieve, because the real cost level seems sometimes higher than the rate level. This can only be overcome in the exploitation of a terminal if subsidies are received, second-hand equipment is used and/or additional terminal services are offered, like for example by renting out areas for container storage or if the terminal operator offers own barge services and pre- and post truck haulage services. Furthermore, it is important to increase the transhipment volume in order to enable a reduction of cost per load unit. This can be accomplished if cost savings in pre- and post truck haulage can result into a larger terminal service area, enabling more customers to serve and hence to increase the volume to be handled at the terminal. In this way, an improvement of pre- and post truck haulage can also positively affect the terminal efficiency.

To increase the market scope of intermodal transport an extension of the number of access points to the rail or barge infrastructural networks can be useful, particularly in the capillaries of the network. For this purpose, in barge transport there may be an interesting role for small-scale, simple (low-cost) terminals (see Figure 8.3) and self(un-)loading vessels (Willems, 1998). The exploitation of such transhipment facilities does not require large handling volumes, and as such, they offer possibilities for small freight flows to be transported in an intermodal way. The feasibility of these handling concepts, however, cannot be considered apart from their position in the existing intermodal barge service networks and the costs of pre- and post truck haulage.

Figure 8.3 'Artist impression' of a 'low cost'-barge terminal

Source: Van den Wall Bake, 1998

8.3.2 The intermodal network (barge and rail services)

Transport costs per load unit in rail or barge transport are in large extent determined by the train length and vessel size, the loading factor of the transport means and the transport distance. The larger the transport means and the load factor are, the lower the fixed costs per load unit will be. These economies of scale which arise from freight bundling are at bottom of the viability of intermodal transport.

Freight bundling can not only accomplish transport costs savings, but can also enable a higher frequency of services. As a result the time between successive departure times of services becomes smaller and hence it can reduce the total transit time of goods. In addition, bundling of freight flows also offers possibilities to serve transport relations, which because of too small volumes otherwise could not be served by intermodal transport.

Since direct intermodal connections usually require large volumes, this is an important observation in view of attracting new, i.e. smaller, freight flows to intermodal transport. Against these advantages of freight bundling, there is the disadvantage of additional transhipment, which make the transport service more expensively, more slowly and possibly also less reliable. Finally, the transport distances are longer compared to direct transport services.

The advantages and disadvantages of bundling must be weighed against each other. In this trade-off the spatial pattern of freight flows (in terms of volume and direction) is a decisive factor. Dependent on how freight flows are bundled, different types of networks are conceivable that can be reduced to four basic bundling or network models (Kreutzberger, 1995).

The point-to-point network or the direct connection is in fact the ideal model: a direct connection without intermediate stops, and hence a short transit time, a high reliability and low costs, because there is no intermediate transhipment. However, the network is only ideal, if the transport volumes are large enough to offer services with a frequency that is acceptable for the users. Table 8.3 shows the minimum required volumes for a daily service for the situation of a service area with three begin- and three end terminals. The hub-and-spoke services, the line services and the collection/distribution services require only 1/3 of the volume by origin-destination relation, which is needed to maintain the point-to-point services.

Looking at daily practice in container barge transport, new services rather start as a point-to-point service despite of its disadvantage that a substantial transport volume is needed. To overcome this problem, services start with relatively small vessels (varying from 32 to 90 TEU capacity), so that an acceptable frequency can be offered immediately (for example 3 services per week). If the transport volume increases, generally first the frequency will be increased and later on larger vessels will be employed. According to this development path a sufficient utilisation rate of the vessels can be maintained. For a 'starting service' of three departures per week with one vessel of 90 TEU-capacity, however, a transport volume of about 20,000 TEU (which is about 12,500 containers) per year is needed. In the situation in which the cycle time of the vessel is too long to employ only one vessel, even a larger volume is necessary. In case of a smaller transport volume than 20,000 TEU such a point-to-point service system is less attractive and another type of network would be more suitable (see Table 8.3).

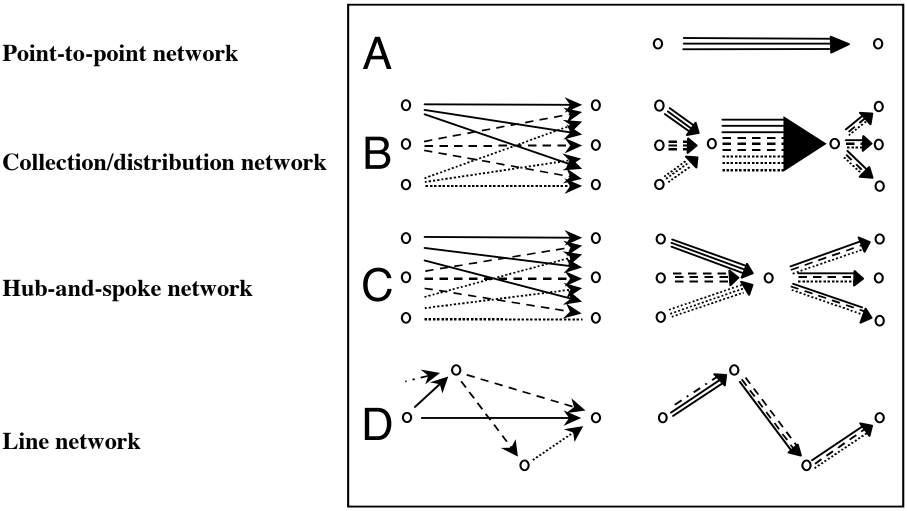
As a matter of fact, this development path regarding the frequency and transport scale of transport services in barge transport is different from rail transport. In rail transport the role of frequency and transport scale is usually the other way around (see Kreutzberger, 2007). This is related to cost structure differences between rail and barge transport. Due to small marginal costs of driving with extra wagons it is usually attractive to start a service immediately with a long train. In order to accomplish a sufficient utilisation rate of the train the frequency of the ‘starting service’ might be low, but will be increased after transport volume increases.

Table 8.3 Required transport volume (in TEU per week) per origin-destination pair, based on 5 services per week, in two directions, a service area of 3 begin- and end-terminals and 85% loading degree

Type of network	Capacity of an inland vessel			Capacity of a train		
	32 TEU	90 TEU	208 TEU	400 m.	500 m.	600 m.
point-point	169	481	1106	272	340	408
Line	56	160	369	90	113	136
Hub & spoke	56	160	369	90	113	136
collection/distribution	56	160	369	90	113	136

Source: Konings, Bontekoning en Maat, own calculations

Figure 8.4 Four basic concepts of freight bundling



Source: Kreutzberger, 1995

In the line network (see Figure 8.4) the intermediate stops enable to transport more cargo and hence to maintain a sufficient utilisation rate of the vessel, but here there is a certain trade-off between the utilisation rate and the transit time. Except for container transport on the Rhine river, this type of network is not very common in barge transport. In particular in short distance transport this is not an attractive option, because it would increase the transit time too much and hence could endanger the competitiveness to road transport. The competition with road-only transport is at shorter distances more severe. Moreover, ownership of terminals plays a role: terminal operators in the Netherlands and Belgium often also act as barge operator and therefore prefer their own terminal to serve. As result of mergers and co-operation agreements between terminals this attitude is, however, gradually changing.

In rail transport a line service is more likely to be observed, also because loading and unloading a train is easier than a vessel, in which containers are piled up. Some rail shuttles have the characteristics of a line service, since they may have some stops at the beginning and/or end of the route. For example, the port of Rotterdam has rail shuttles that start at Rotterdam Maasvlakte and make an intermediate stop at Rail Service Centre Waalhaven Rotterdam and then run to Italy. Since this type of service is a combination of a point-to-point service and a line service it is sometimes defined as a semi-shuttle. Nevertheless, pure line concepts with stops underway are rare, although several concepts have been tried in practice, like for example the Light-Combi concept in Sweden (Barthel and Woxenius, 2004).

The collection/distribution network is an appropriate type of network if freight flows with different directions of origin have the same direction of destination. The advantages of freight bundling arise on the main (barge or rail) haul. This network is neither applied in barge transport nor in rail transport, because the feedering of small volumes is expensive and difficult to be compensated by the network advantages on the main haul.

The hub-and-spoke network is the network model in which the effects of freight bundling are maximal (Klaus, 1985). In this network, all origins and destinations are connected to each other via a centrally located terminal (hub), which means that freight for different destinations is always jointly transported. Due to its specific bundling characteristics it offers possibilities to develop transport services on new relations where the transport flows are (still) too small for direct connections. In a hub-and-spoke network with 3 spoke-connections on average only one third of the total transport volume of a direct connection is needed to offer such a spoke-connection with a same frequency as a point-to-point service.

Due to these features this network offers interesting opportunities for market expansion of intermodal transport. The rail transport sector is already familiar with the hub-and-spoke network. In Belgium there is the NEN (North European Network) with a shunting-hub in Muizen. The NEN hub-and-spoke network features a really star-shaped network. In addition, there is the NARCON (National rail container Network) hub-and-spoke network which has its hubterminal in Antwerp. In this network the inland terminals of Kortrijk, Moeskroen, Charleroi and Athus, as well as terminal of Zeebrugge, are linked with different quays in the port of Antwerp via the mainhub-terminal of Antwerp. In this network daily trains run to and from the mainhub-terminal. In principle, this network was developed to bundle the container flows in the port in order to make rail hinterland transport more attractive. Actually this network keeps the middle between a hub-and-spoke network and a collection/distribution network. The transported volume in NARCON was almost 140,000 TEU in 2005.

In intermodal barge transport the hub-and-spoke network is still unknown. An important explanation for this is that container barge transport still consists of almost exclusively hinterland transport of maritime containers. The containers have always the seaport as an origin or destination. In such a situation point-to-point connections are more logical than star-shaped connections.

In general, a pre-condition for a hub-and-spoke network to perform well is the synchronisation of arrival times of the trains or barges as well as smart transhipment and exchanging operations at the hub (Bontekoning, 2006; Konings, 2006).

In addition to the transport volumes and the transport organisation the quality of the physical infrastructure, i.e. the situation, capacity and quality of the rail lines and inland waterways and terminals, will be important for the feasibility of the different service networks. The location of the line infrastructure and terminals imposes specific geographical restrictions, as a result of which for certain network configurations the detour distances become too large to be competitive to road-only transport. The shorter the transport distance, the stronger the barrier of a detour distance is. Moreover, barge transport is confronted with a large variation in the quality of waterways. Regarding container barge transport this is manifested by differences in admissible vessel size, altitude restrictions at bridges and possible loss of time to pass by locks or bridges. All these circumstances also influence the choice of the type of network.

Figure 8.5 The Belgium waterway network by classification of waterways and the location of barge inland terminals (in 2008)*

* Manuport container terminal (nr. 10) is a barge terminal in the port of Antwerp. In 2006 (publication date of this paper) the terminals of Batop (nr. 9) and Groep Gheys (nr. 11) were not established yet.

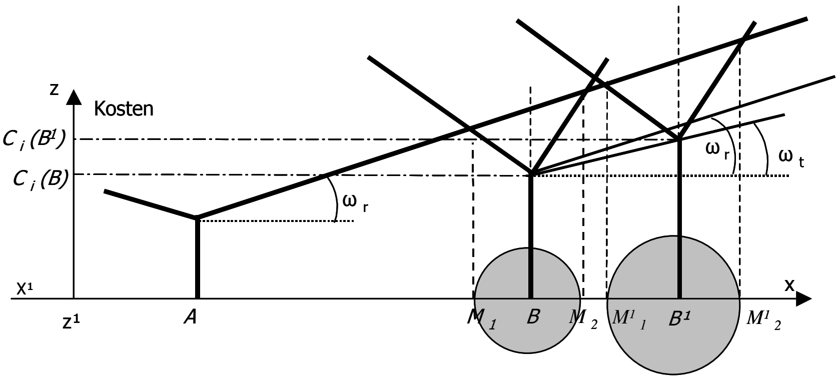
Source: Promotie Binnenvaart Vlaanderen

Figure 8.5 shows a number of infrastructural conditions for barge transport. The best navigable waterways are situated around Antwerp and Ghent and have both a North-South - and an East-West orientation. These cities could therefore potentially act as exchange point (hub) for new barge transport services which could link inland terminals mutually. The location Antwerp has the advantage that it already functions as a node for hinterland traffic. This means that continental freight flows could be bundled here with the existing maritime freight flows. In the Belgian inland waterways network also two ring structures can be noticed. One that runs from Antwerp to Hasselt, Liège, Namen, Charleroi and Brussels and another one which runs from Antwerp to Ghent, Kortrijk, Mons and Brussels. Although the quality of the waterways on these routes varies, it is conceivable to develop barge line services for continental cargo along these routes. A detailed study, in which the potential transport volumes and conditions regarding the infrastructure in these concrete cases are examined, has to show if such new types of network are really promising.

These more complex network services, involving smart bundling of freight, aim to reduce the costs and to improve the quality of existing intermodal services or to improve the feasibility to establish new intermodal services. In terms of market scope (see Figure 8.2) this means that the costs of a barge- or rail haul, represented above point B, are reduced, taking into account a compensation for the costs of a possible intermediate transhipment. In this way the terminal service area of existing terminals can be enlarged. At other locations a viable situation can arise for new terminals and services.

The role of the transport distance on the competitiveness of intermodal transport is to some extent also related to pre- and post truck haulage (see also section 8.3.3) but, ceterus paribus, a longer barge or rail haul results into a larger market scope (see Figure 8.6). The cost per kilometre per load unit for rail or barge transport (ω_t) are – with a reasonable utilisation rate of these transport means - lower than for a truck (ω_r). Therefore, the longer the rail or barge haul, the larger the cost difference with road transport becomes and the larger the distance in pre- and post truck haulage can be. In practice this effect is very recognizable. At the relation Antwerp - Meerhout (a distance of 75 km) intermodal barge transport can compete with road transport in an area which roughly extends to 30 km in the direction of Antwerp to 60 km in the direction of Genk/Hasselt. On the other hand, daily practice for example shows that it is feasible in intermodal rail transport to North-Italy (at a distance of about 1,000 km) to bring the containers over a distance of 150 km from the terminal to the customers.

Figure 8.6 The effect of longer rail or barge hauls on the market scope of intermodal transport



Source: Adapted from Nierat, 1997

8.3.3 Pre- and post-truck haulage

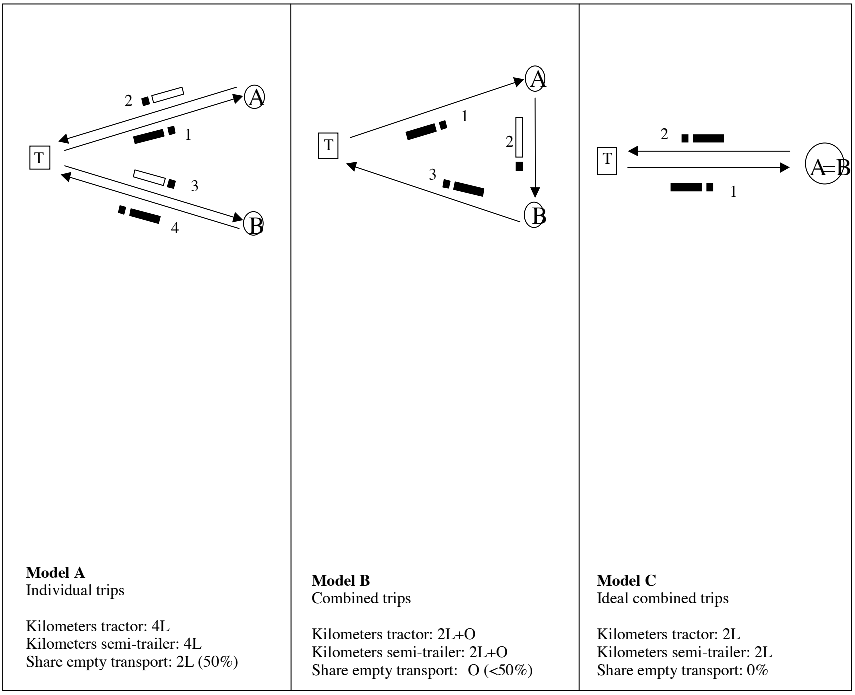
Although the distance in pre-and post truck hauls is generally limited (less than 25 km), the cost share of these hauls in the intermodal chain costs is relatively large (Morlok et al., 1995; Morlok and Spasovic, 1994; Spasovic and Morlok, 1993; Höltgen, 1996; Fowkes et already 1991; Niérat, 1997). Transcare (1997) shows that in an intermodal chain with a rail haul of 500 km and a truck haul distance of 25 km at both ends of the chain, the cost share easily amounts to 50% of the total chain costs. Findings of Macharis and Verbeke (2004) confirm the large weight of pre- and post truck hauls in the intermodal transport bill. In their analysis an intermodal barge transport chain from the seaport to the hinterland was considered, in which only a post truck haul was needed. For an intermodal transport service based on a barge haul of 55 kilometres and a truck haul of 20 kilometres, a total price was observed, which consisted of 25% for barge transport, 30% for the transhipment and 45% for post truck haulage. Possible savings in the truck haulage part of the intermodal transport chain could therefore have a large impact on the cost competitiveness of intermodal transport.

Looking at the cost structure of truck hauls both the variable or kilometre costs and the fixed or time costs are of great importance. In Figure 8.2 the kilometre costs are represented by ω_i and the time costs are part of the costs shown above point B. Given these two different cost components there are two driving forces for the performing of truck hauls. On the one hand the driver is to maximize the productivity of resources (equipment and labor), or in other words, trying to execute paid trips as much as possible. This enables to reduce the fixed costs per trip. On the other hand the driver is to minimize the number of empty vehicle kilometers in order to reduce the variable costs. The first goal is related to, in literature well known, 'stay-with' or 'drop-and-pick' processes in truck haul operations. The second goal refers to using opportunities to combine trips.

In the *stay with-trips* the tractor remains coupled to the semi-trailer during stuffing or stripping of a container. After unloading at a customer three situations can occur: a) the combination drives back to the terminal empty, b) the container is loaded elsewhere and than the truck returns to the terminal or c) the container is reloaded at the same address where it was unloaded and than transported to the terminal. The share of empty transport varies from 50% to 0% (see Figure 8.7). The fixed costs of these trips are relatively high, because the tractor and driver are waiting during (un)loading the container and therefore they are unproductive.

In *drop-and-pick-trips* the tractor and semi-trailer of a truck are split at the shippers' premise. During (un)loading the container, the tractor returns to the terminal, with or without a new semi-trailer and container. It can also first move on to a second shipper to fetch another semi-trailer with a container. Semi-trailers with containers that are left behind are picked up by the tractor at a later moment. In these kinds of trips the time costs are relatively lower than in stay-with trips, but the kilometre costs are higher, because of more empty hauls. The share of empty trips can become 75% (see Figure 8.8).

Figure 8.7 'Stay with' production model (tractor and semi-trailer of a truck stay together): three basic patterns



Model A
Individual trips

Kilometers tractor: 4L
Kilometers semi-trailer: 4L
Share empty transport: 2L (50%)

Model B
Combined trips

Kilometers tractor: 2L+O
Kilometers semi-trailer: 2L+O
Share empty transport: O (<50%)

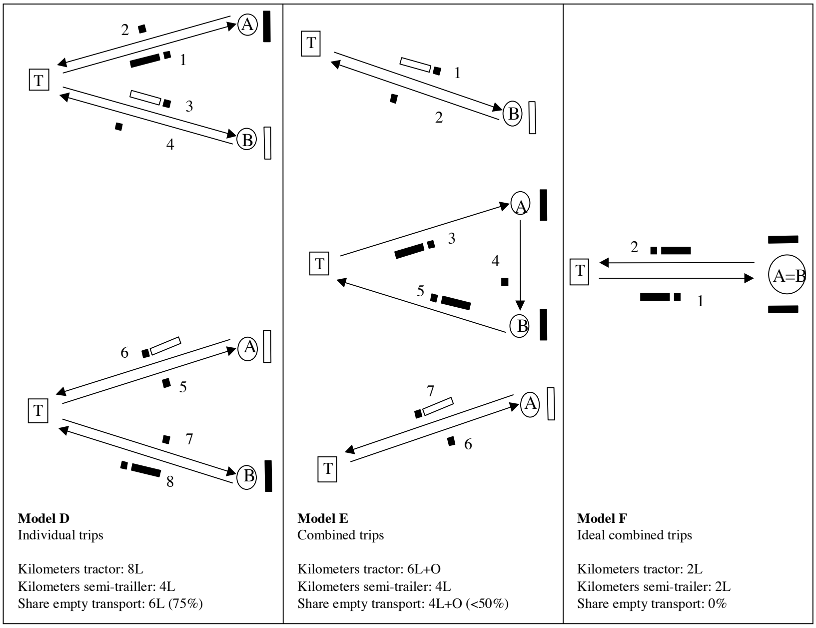
Model C
Ideal combined trips

Kilometers tractor: 2L
Kilometers semi-trailer: 2L
Share empty transport: 0%

Legend:

T = terminal
Ⓐ = customer A
Ⓑ = customer B
▬▪ = tractor/semi-trailercombination with loaden container
▭▪ = tractor/semi-trailercombination with empty container
1,2,3,4 = numbers indicate the order of activities
L = distance from terminal to customer
O = distance between customers

Figure 8.8 'Drop and pick' production model (tractor and semi-trailer of a truck are split:) three basic patterns



Model D
Individual trips

Kilometers tractor: 8L
Kilometers semi-trailler: 4L
Share empty transport: 6L (75%)

Model E
Combined trips

Kilometers tractor: 6L+O
Kilometers semi-trailer: 4L
Share empty transport: 4L+O (<50%)

Model F
Ideal combined trips

Kilometers tractor: 2L
Kilometers semi-trailer: 2L
Share empty transport: 0%

Legend:

T = terminal
Ⓐ = customer A
Ⓑ = customer B
▬▪ = tractor/semi-trailercombination with loaden container
▭▪ = tractor/semi-trailercombination with empty container
▬ = semi-trailer with loaden container
▭ = semi-trailer with empty container
▪ = tractor
1,2,3,4 = numbers indicate the order of activities
L = distance from terminal to customer
O = distance between customers

As the total costs of these truck hauls are not only determined by the cost of driving, but also by costs related to the trip time (including the time spent at terminals and customers) a trip production model that results into less kilometres is therefore not always the most efficient solution. The smaller the transport distance is the more weight the duration time at terminals and shippers gets and in these circumstances drop-and-pick trips will become more attractive. The relationship between time and kilometre costs determines at which distance a break-even point between stay-with- and drop-and-pick trips will be achieved.

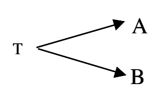
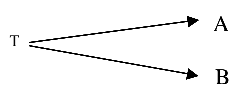
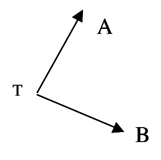
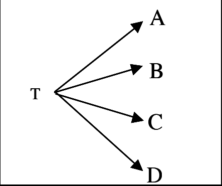
Since the costs of trips with empty containers have to be taken into account in the rates offered to customers, the number of empty hauls is very relevant. The number of empty hauls will influence the coefficient ω_i in the model described in the previous section. The share of empty hauls can be reduced by combining trips, which result in a smaller coefficient ω_i. As can be derived from Figure 8.2 a smaller ω_i results in a flatter curve, i.e. the terminal service area increases.

In addition to a reduction of empty transport, productivity improvements in pre- and post truck hauls can also lead to a larger market scope of the terminal. An important way to improve productivity is to reduce the duration time at terminals and shippers. This would be possible if the document settlement at terminals and customers could be smoother, if there are a sufficient number of ramps at shippers and consignees, a sufficient number of staff for stripping and stuffing containers, sufficient container handling capacity at terminals, but also by good communication between the actors concerned with these truck haul operations. Increasing the time windows (opening hours) to visit terminals and customers could also increase productivity, because it enables truckers to avoid congestion at terminals and roads in peak hours and therefore the time spent in trips can be reduced.

In addition, the planning of trips is also very importance for the transport efficiency of these truck hauls. Studies (Walker, 1992; Morlok, 1994) have shown that a central planning of trips can lead to 30% cost savings. These savings can be achieved because in the model of central planning it is easier to combine trips, due to the coordination and control over a large number of trips. Most inland terminals in Europe apply this planning model, but at the terminals in seaports usually many trucking firms are involved, which – fostered by a strong competition – execute these trips, however, in an uncoordinated way.

The efficiency of pre- and post truck hauls, however, is not only determined by operational and organizational issues, but as a matter of fact also by several external circumstances, the nature of the transport volumes in particular. Obviously the total transport volume is important, but also the possible imbalance of inbound and outbound cargo flows, because this affects the share of empty transport. In addition, the spatial dimension of the transport flows is important, or in other words, the spatial features of the customers in the terminal service area: the distance from terminal to customers, the distribution of customers and the customer density (see Figure 8.9). If the distance from terminal to customers increases, also the costs of hauls increase. The distribution of customers determines the potential benefits of combined trips: if customers are located near each other, the smaller the detour distance to visit another customer is and the lower the haul costs can be. In ideal trips – trips in which a container is loaded and unloaded at the same address – the detour distance is zero. The customer density is defined as the number of customers in a terminal service area of a given size. This means that if the customer density is high the transport volume is spread over a large number of pick up and delivery points. In that situation the average detour distance to visit customers becomes smaller, but at the same time the chance to get ideal combined trips (without detours) decreases. Therefore, the effect of customer density on the performance of truck hauls is ambiguous. The location of customers, however, is often a fact and can not be changed by the trucking companies.

Figure 8.9 Spatial variables relevant for the performance of truck haul operations: distance terminal - customer, distribution of customers and customer density (T = terminal; A, B, C and D = customers)

Starting situation	Larger distance	Larger customer distribution	Higher customer density
			

Source: Konings, Bontekoning en Maat, own drawing

8.4 Conclusions

In this paper we have addressed three clues to improve the competitiveness of intermodal transport to road-only transport and hence to increase the market share of intermodal transport. These clues are related to the links in an intermodal transport chain: the main haul by barge or rail transport, the exchange of load units at terminals and pre- and post truck hauls.

The production model for intermodal barge or rail transport services proves to be important for the costs and quality (in terms of frequencies) of these transport services, and this is where the service network structure comes into play. Simple networks, such as line services and point-to-point services have specific advantages, but generally are less appropriate to transport small freight flows by barges and trains, which make it difficult to attract new freight flows to intermodal transport.

For this purpose more complex service networks, such as collection/distribution networks and hub-and-spoke networks, would be more appropriate. The potential cost savings of employing these more complex networks is, however, tempered by the inevitable costs of additional transhipment. This means that such networks are mainly promising on longer distances, where the comparative cost advantage of rail and barge transport comes out well. In the Belgian context one should think here about international networks and transport flows, because on national scale the distances in Belgium are rather short.

With regard to traditional intermodal terminals there are a few possibilities to achieve substantial cost reductions. These links in the chain could therefore better focus on improving their quality of services: on the one hand by ensuring a smooth and reliable handling of the containers and on the other hand by expanding their complementary services, like for instance offering customs facilities.

The relative high costs of pre- and post truck haulage make strategies to reduce these costs interesting to improve the competitiveness of intermodal transport. Two major strategies can be distinguished to accomplish this:

1. an improvement of the efficiency of pre- and post truck hauls. This assumes several measures to enable a higher productivity in this business, but also using opportunities to combine trips. In this respect the so-called LZV's (long and/or heavy trucks) can prove their value. Since these trucks have a container loading capacity of 3 TEU, these trucks could produce considerable cost savings. Based on the preliminary results of the current pilot with these trucks in The Netherlands, a definite admission of the LZV's may be expected. The attitude towards these trucks in Belgium so far has been sceptical, because of infrastructural bottlenecks and, related to that, doubts about the safety of those trucks.
2. an increase of the accessibility of intermodal transport, both literally in a physical way and figuratively in an economic way. On the one hand this means aiming at shorter truck haul distances. The distance from terminal to customer is an important factor for the costs of pre- and post truck haulage, although what is considered as an economically acceptable distance is very dependent on the distance of the barge or rail haul (because this determines the share of truck haul costs in the total costs). On the other hand, there should be enough cargo in the neighborhood of the terminal to make intermodal transport services viable. If there is sufficient cargo this also offers opportunities for efficient truck hauls, i.e. the possibility to combine trips.

A greater accessibility to intermodal transport can increase the demand for intermodal transport and hence also the transshipment volume of a terminal, affecting the transshipment costs positively. Given a certain level of intermodal transport chain costs, a lowering of transshipment costs allows higher truck haul costs, i.e. an extension of the terminal service area, which creates better conditions to combine trips that could then reduce the truck haul costs. In brief, the efficiency in truck hauls contributes to the accessibility of intermodal transport in economic terms and vice versa. Various parameters like transshipment volumes, transshipment costs, size of the terminal service areas as well as opportunities for central planning of trips seem to be much related. Location policies regarding terminals and companies (shippers and consignees) are key factors to influence these variables into the direction of a better competitive position of intermodal transport. Hence, relevant questions are:

- Is there a need for more intermodal terminals and if so, where should they be located? What are favourable locations for these new terminals?
- What are the possibilities to get potential customers of intermodal transport located in the immediacy of terminals?

The most promising solution, at least in European context, indicates into the direction of a so called ‘dispersed spatial concentration’ as a planning instrument to stimulate intermodal transport. This is an approach focused on the development of (large) business areas that are directly accessible by two or more modes of transport (road and rail and/or barge) through the presence of an intermodal terminal at the site of the business area. Since companies are located very nearby the terminal at a multimodal business area, the truck haul operations may be performed by terminal transport equipment offering substantial cost savings in these trips between terminal and shippers/consignees. The number of such business areas is still limited compared to the number of business areas that are only accessible by road.

The challenge is to seduce companies to locate there, but it is also important to attract the ‘most suited’, i.e. very transport intensive, companies, such as forwarders and logistic service providers. So far regional and local governments in Europe do not have the appropriate policy instruments to perform such a policy effectively. In addition to the development of these multimodal business areas it is also useful to develop business areas on short distance of intermodal barge or rail terminals. Although haulage by truck is then needed, the concentration of customers offers favorable conditions for combined trips and drop-and-pick trips, and hence contributes to efficient truck hauls.

In the spatial planning of companies and terminals there is a challenge to find a balance between sufficient freight volume to operate a terminal, minimizing distances in pre- and post truck hauls and maximizing possibilities to combine trips in pre- and post truck haulage. On the one hand the intermodal network should not have a very coarse structure, because this may result into too long distances in pre- and post truck haulage. On the other hand the intermodal network structure should not be too fine, otherwise freight volumes may be too small to operate a terminal profitable.

The large share of pre- and post truck haulage costs in the total intermodal chain costs seems a strong argument to support the development of a more dense terminal landscape, in which there is a more profound role for small terminals. This is only economically and socially feasible if the exploitation of these terminals can be profitable. From this perspective the need for new transshipment- and terminal concepts, like for instance the low-cost barge terminal and self unloading vessels as mentioned before, is rational. In this way the market penetration of intermodal barge transport can be supported.

Of course the choice between road-only transport and intermodal transport will not be determined by transport costs only. Transport quality aspects are gaining importance, among which is transport reliability. The possibility of intermodal transport to offer reliable transport services is an important feature, particularly in view of a deterioration of the reliability of road transport as a result of increasing congestion. It is for this reason that inland terminals are used, in addition to storage of empty containers, as a storage area for container cargo. Containers with cargo can then be delivered from the inland terminal to the customer on demand in a reliable and flexible way, in particular if the customer is located nearby the terminal. Hence, spatial concentration of businesses that receive or dispatch containers is not only beneficial for intermodal transport from the transport cost perspective, but it also strengthens the competitiveness of intermodal transport regarding the integral logistical trade-off between different transport modes.

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9 The competitiveness of the river-sea transport system: market perspectives on the United Kingdom – Germany corridor

Konings, R. and M. Ludema (2000) The competitiveness of the river-sea transport system: market perspectives on the United Kingdom – Germany corridor, in: *Journal of Transport Geography* 8(3), pp. 221 – 228. Copyright © Elsevier Science Ltd.

Abstract

River-sea transport is an interesting intermodal transport concept by definition, because seaport transhipment is avoided. Nevertheless, the concept has not been widely developed in Europe. River conditions, draft restrictions in particular, generally form a major impediment. This restricts physical opportunities for this concept to a very limited number of transport corridors, and even then it is faced by limitations influencing the economic attractiveness of such a concept. This paper evaluates the opportunities of a river-sea transport concept, in which specially designed push barges are being used to face these limitations. The concept envisages a service on the United Kingdom - Germany corridor, and examines its competitiveness with regard to a number of alternative transport modes. To this end, a model is developed which can be used as a tool to determine the optimal choice of ports to serve. The model considers the transport qualities and available transport volume collectively in order to determine the most interesting transport service of such a river-sea push barge system. Based on the model results it is recommended to start transport services between Hull and a Lower Rhine inland port (i.e. Dormagen).

9.1 Introduction

River-sea transport is an interesting intermodal transport concept by nature. It offers a seamless connection between the land and sea leg of a cross-sea journey: a coastal seaport transhipment is avoided. Because of the avoidance of this transhipment river-sea transport may result in substantial time and cost savings in the total intermodal transport chain, and even more so if such savings can be obtained at both ends of the transport chain in case pre- and end-haulage are needless.

The concept of river-sea transport is not a new phenomenon in itself. It is true that river sea transport has been developed in Europe, but substantial traffic volumes are only found on a very limited number of routes (see also Rissoan, 1994). As a matter of fact, the quality of the inland waterways network is a decisive factor for the development of river-sea transport. Even on the well-developed West European waterways one is confronted with several restrictions, which limit the geographical range of river-sea transport. In general, river conditions, draught restrictions in particular, form a major impediment for river-sea vessels to operate under the most competitive conditions. A river-sea transport concept intended to meet these conditions is the River-Sea Push Barge (or RSPB) system. The technical design of the concept was developed by Vecomar International and Marine Heavy Lift Partners in the Netherlands. The core of the RSPB concept is the construction of specially-designed push barges which can be used at inland waterways and at sea as well. The major characteristic of these barges is the possibility to adjust to different draught conditions in an optimal way. On the one hand the barges should be warranted as seaworthy and on the other hand they should provide a very limited draught for extended accessibility on inland waterways.

A study has been conducted in which the market perspectives of this transport system have been investigated. This study focused on the transport corridor between inland harbours along the Rhine in Germany and between seaports on the coast of United Kingdom, as the most interesting starting point for introducing this concept into the market.

9.2 The characteristics of the River-Sea Push Barge system

The principal element of RSPB is the application of a push barge with a very shallow draught, making it possible to navigate the Rhine as far inland as Strasbourg. With conventional coasters, such as are currently used on the Rhine, this is either impossible or commercially unattractive, because:

- water levels in the Rhine cause too many problems;
- conventional coasters have too small a capacity;
- travelling inland waters with such ships is relatively expensive;
- the turnaround time of these expensive ships is too slow.

By contrast, the push barge developed for RSPB is relatively inexpensive and has a large capacity, so the shortcomings listed above no longer apply. A shallow draught is achieved by the use of a pontoon with variable ballast options, above which a superstructure is built, which is furnished with specific loads (such as rolling stock or containers) in mind. Naturally, the design takes account of the construction size and classification regulations applying to Rhine push barge constructions. The push barge will measure 110-m (length overall) by 22-m width.

The ballast options of the push barge allow unhindered passage in the Rhine. When water levels are high, the barges are ballasted in order to allow the vessel to pass under bridges, while in low water the barges' shallow draught enable almost unlimited movement. The height of the barge is related to the headroom allowed by the bridges over the Rhine, but is no less than 9.10 m.

On the Rhine, the barge is pushed by, and linked to, a conventional (river) pusher tug using a method already widely employed. For sea transport, use is made of an existing tug fitted with a so-called Arti-couple system, a coupling method which was specially developed for this application. The barge's ballast options are used to give the barge the required draught for its sea passage.

The operational processes are as follows. The river push boat sails the barge from the hinterland into the seaport, there change of push boat takes place. Next the seagoing push boat sails the push barge to the seaport of destination, there the push barge will be discharged or eventually again been taken over by a river push boat to be sailed to its final inland (port of) destination. Because of rapid interchange of the push boats in the seaport, the duration time of the load in the seaport will be very short (maximum 2 hours). Figure 9.1 gives a diagrammatic representation of the RSPB transport concept.

9.3 The competitive power of RSPB in relation to the potential ports of call

An essential component of the successful introduction of RSPB is an understanding question of the ports between which such a service can best be offered. Factors determining the 'best' ports will include not only potential freight volumes but also the quality of any alternative transport options open for the route in question. The consideration that both these aspects – freight volumes and competition – have to be examined in their mutual relation underpins the following transport choice and demand model.

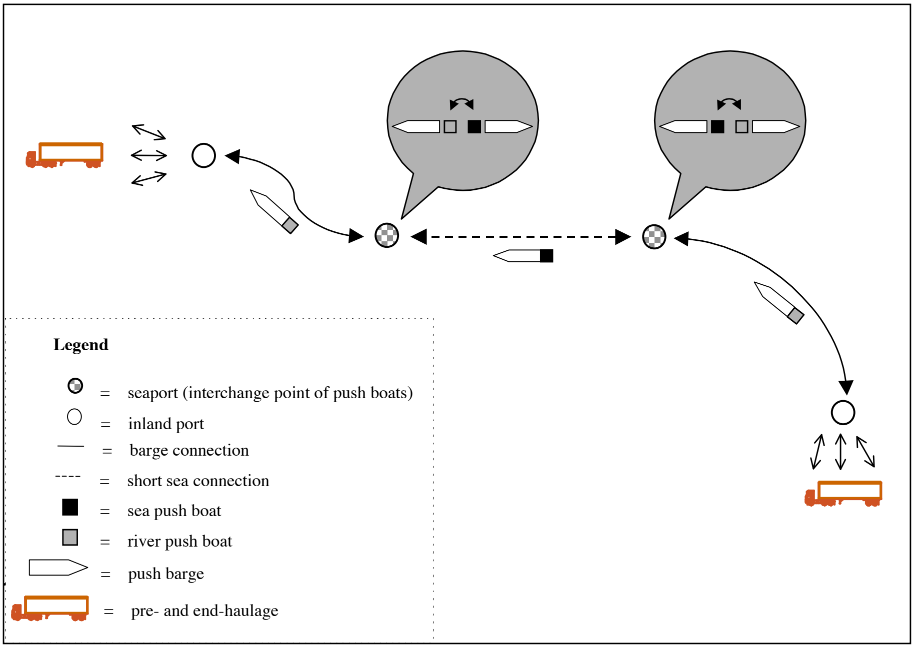
9.3.1 Transport choice and demand model

This model comprises a component expressing the transport choice and a component by which the transport demand is estimated (see also Quandt & Baumol, 1966). The model specifies the decision framework of the shipper's modal choice, and it can be used to calculate a modal split for every route. However, this modal split is also dependent on the selected RSPB ports of call, because the location of these ports determines the performance of RSPB relative to alternative options and therefore affects the shipper's ultimate choice. Once the total transport demand and the port-dependent modal split are known, a future RSPB transport share can be calculated for every alternative RSPB port of call, and it can be determined which ports of call the RSPB concept should select in order to recruit the most business.

9.3.2 Assumptions of the model

Within the framework of this research, a number of choices were made and a number of constraints imposed on the model. These choices and constraints are described in the following subsections.

Figure 9.1 The River-Sea Push Barge system in the intermodal transport chain



The potential ports of call

For Germany, three possible ports were taken into consideration: Dormagen, Mainz and Germersheim. These were chosen both on the basis of their terminal facilities and their relative location. Dormagen represents one of the options in the so-called Lower Rhine; Mainz lies at a strategic point in the Middle Rhine; and the more southerly port of Germersheim can be regarded as an operating base for the Upper Rhine.

In the United Kingdom the port of Hull was chosen, with no alternative ports of call being taken into consideration. This had to do with the lack of UK regional data on freight origins and destinations, which invalidated the usefulness of considerations relating ports of call with different freight volumes.

Alternative transport concepts

The RSPB concept was compared with the most important existing transport options on the UK-Germany corridor, namely road/ferry transport and the barge/short sea shipping chain. Road/ferry transport is well known as a rapid alternative, thanks to high transport speeds (both by road and by water) and short transhipment times (roll-on-roll-off) (Buis and Bovy, 1997). The barge/short sea transport option has the reputation of being relatively slow, since goods have to be transhipped in three ports, but it has the advantage of being relatively inexpensive. Traditional sea-river transport using coasters has not been taken into consideration here, since this plays a negligible role in the transport of intermodal freight, i.e.

intermodal load units (such as trailers, containers and swap bodies), while this research is focussed on unitized cargo.

Regions and freight flows

The attractiveness of a port of call depends, amongst other factors, on its location with regard to the freight; in other words, the combination of the potential freight volumes and their distance from a port will determine the attractiveness of that port. Data on the nature of the freight flows between the two countries, classified according to the regions of origin and of destination, can provide insight into this issue. The delineation of these regions takes account of their relevance for RSPB and the spatial scale level for which freight flow data was available.

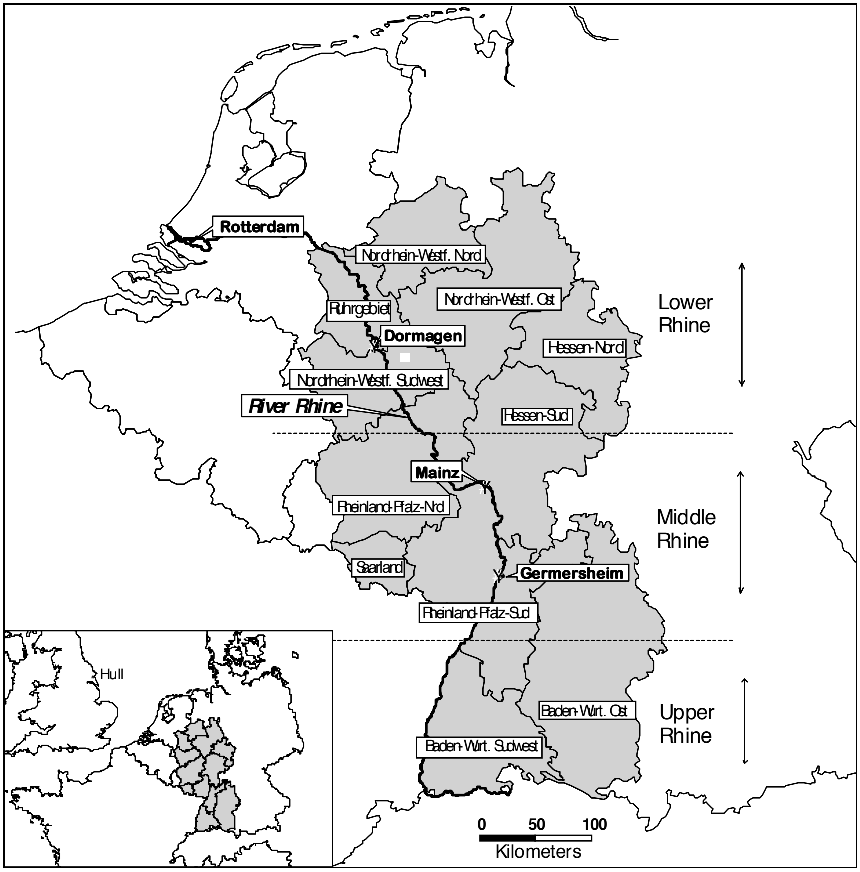
For Germany, the regions through which the Rhine flows, together with a number of adjacent regions lying within a short distance of the Rhine, were included in the RSPB's proposed catchment area. These comprised five *Bundesländern* subdivided into 12 subregions (see Figure 9.2). For reasons concerning available data, consideration of the UK was limited to England as a whole; further subdivision into regional areas within England was impossible. In the model employed, the relative location of the port with regard to the freight was calculated using a 'gravity model'. To this end a 'freight supply centre of gravity' was established for every region.

The shipper's decision-making process regarding modal choice: transport costs and transport time

Numerous considerations play a role in a shipper's choice of transport. Extensive research has been carried out into this (i.e. Jeffs, 1985, NEA/NEI, 1990; NIPO, 1997). The following four aspects are repeatedly cited as being important factors: costs, time, reliability and the prevention of damage. In comparing transport alternatives in our model, we shall concentrate on the significance of the first two: the cost and time factors.

It is widely held that shippers will choose the transport service which offers the 'least transport resistance': in other words, the option which offers the best combination of door-to-door transport cost and time (Tavasszy, 1996). This introduces the concept of 'generalized transport cost', since the calculation of transport resistance involves expressing both transport times and transport prices by means of a single financial denominator.

Figure 9.2 Considered regions and ports for the River-Sea Push Barge system



However, the valuation of transport time is a troublesome business, especially in an aggregated model such as the one used here. This is because specific company-related logistic circumstances play a role that must be taken into account alongside the role played by commodity characteristics (see also Blauwens, 1991). In the valuation of time, the value of the commodity is generally accorded the most important role; for instance, one well-known method involves valuing time exclusively on the basis of the interest costs incurred by the commodities. This is a simple and clear approach, but in our view a too limited one; another, more sound approach is to value time on the basis of the so-called 'revealed preference' principle. Since this valuation is derived from actually observed behaviour, this approach may be expected to yield the best estimates (see also Blauwens and Van de Voorde, 1988). However, this technique requires extensive and detailed data on transported commodities, data which were not available in the present study.

We have opted here for a method which is based on commodity interest costs, but which also takes some account of the costs associated with transport times, such as those incurred by the risk of devaluation, spoiling, etc, and the costs arising out of the need to keep safety reserve stocks (see also Blauwens, 1991). For practical reasons, these additional costs are also expressed as a percentage of the value of the product. The total discount rate, interest costs plus additional costs, was set at 12% of the value of the product. This transformation of time into money makes it possible to calculate the generalized transport costs using the following formula (see also Groothedde and Tavasszy, 1997):

$$C_{s,m} = M_s + v_m T_s$$

$C_{s,m}$ = generalized transport costs (€/unit)
M_s = transport rate of transport service s (€/unit)
v_m = transport time valuation of product (group) m (€hours/unit)
T_s = transport time of transport service s (hours)

In order to calculate the generalized transport costs, various sources of market data on prices and times were consulted. Data on the value of products were obtained from 1991 import and export figures published by the British DETR (Department of the Environment Transport and the Regions). The weighted average value of the products transported between the UK and Germany was calculated to be €2,90 per kg.

Using the generalized costs, the transport resistances offered by the various different transport services could be calculated and compared. The comparison of the resistances finally leads to a modal split.

Unitized cargo

The analysis focused on freight most suitable for intermodal transport, namely freight transported in containers. Data regarding container transport between United Kingdom and the German regions were provided by NEA figures for the year 1992. Such detailed data were not available for a more recent year. Of course, the volume of these transport flows may have changed over recent years, but it is very unlikely that regional patterns of transport flow have also changed radically within this time span. Since it was the regional differences in transport flows which were the most important for the purposes of our analysis, the data used were adequate to the task. With regard to the loading weight of container units, we have assumed an average freight weight of 22.5 tonnes.

9.3.3 Model results

In order to calculate the transport resistances, first of all the transit times and integrated transport costs were calculated for the various routes. A comparison of these transit times for the various transport concepts is given in Table 9.1.

Table 9.1 shows the strong position enjoyed by road/ferry transport with regard to these transit times; Hull can be reached from practically every one of the German regions considered within a day. The RSPB concept offers more or less the same possibilities as those offered by the barge/short sea combination. For transport from the more southerly regions of Germany, the RSPB option offers a markedly shorter transit time than does barge/short sea (with time gains of up to 22 hours). This is because in transporting goods out of southern Germany, the initial road transport to Dormagen saves time compared with barge services, which will generally start at the closest inland shipping port.

In the event that RSPB services start in Mainz, then depending on the regional freight origins and destination it is still possible to save up to 12 hours of transit time compared to the barge/short sea chain, provided this chain always uses the closest inland shipping port. Since on this central part of the Rhine river (between Cologne and Wörth) draft and height clearance limitations for common inland shipping vessels only sporadic occur, it is very common to sail to an inland shipping port as close as possible to the origin or destination of the load. With a view to minimizing transit times, an RSPB service would always prefer to depart from Dormagen.

Table 9.1 Freight transport transit time between German regions and Hull, UK (in hours)

	Mode of transport		
Region	**RSPB***	**Road/ferry**	**Barge/short sea**
Nordrhein Wf. Nord	46	19	47
Nordrhein Wf. Ost	45	19	46
Ruhrgebiet	44	18	45
Nordrhein Wf. Sud	43	19	49
Hessen Nord	48	22	53
Hessen Sud	47	22	62
Rheinland Pf. Nord	45	20	56
Rheinland Pf. Sud	48	23	66
Saarland	48	22	70
Baden Wb. Nord	49	24	70
Baden Wb. Ost	50	25	71
Baden Wb. West	52	26	72

* *RSPB times are calculated from the port of Dormagen*

As far as the transport costs are concerned, however, the picture is a little more subtle. The relatively high costs of pre- and end-haulage by road mean that the RSPB concept and the barge/short sea chain both prefer to use the nearest port of departure. For RSPB, Dormagen is the closest port for freight loads associated with regions adjacent to the Lower Rhine (Nordrhein Westfalen), Mainz for the Middle Rhine (Rheinland Pfalz, Hessen and Saarland) and Germersheim for the Upper Rhine (Baden Württemberg). Cost comparison between the three concepts gives RSPB a favourable position, with regard to the barge/short sea option but especially compared to road/ferry transport, which is the most expensive option from all the regions considered.

On the basis of these transport times and costs, the generalized transport costs and then the transport resistances were calculated, and on the basis of these costs and resistances a modal split was estimated for each regional route. The results describe the situation in which RSPB uses Dormagen as its port of call (see Table 9.2). With the exception of the sub-regions in Baden Württemberg, the RSPB approach scores higher than both the road/ferry option and the barge/short sea combination. The strongest competition for RSPB comes from the barge/short sea option. The road/ferry option is markedly faster than both alternatives, but all in all the time gains provided are clearly insufficient to make the road/ferry option an important threat to either the barge/short sea or the RSPB route.

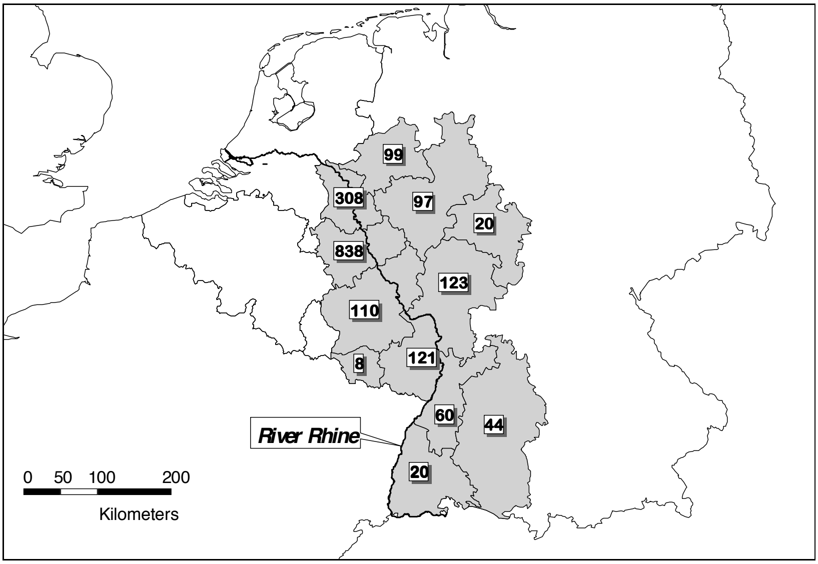
Next, the modal split data were applied to the regional transport volumes, which made it possible to determine which choice of port of call would give the RSPB option the best load maximalization. The regional distribution of container transport between the German regions considered and the UK is shown in Figure 9.3.

Table 9.2 Modal split between German regions and United Kingdom (in %)

	Mode of transport		
Region	**RSPB***	**Road/ferry**	**Barge/short sea**
Nordrhein Wf. Nord	69	15	16
Nordrhein Wf. Ost	76	8	16
Ruhrgebiet	79	7	14
Nordrhein Wf. Sud	87	4	10
Hessen Nord	70	20	10
Hessen Sud	57	9	34
Rheinland Pf. Nord	74	7	19
Rheinland Pf. Sud	54	13	33
Saarland	65	21	13
Baden Wb. Nord	25	9	66
Baden Wb. Ost	25	10	65
Baden Wb. West	19	16	66

* *Calculation of RSPB share is based on Dormagen as the port of call for RSPB*

Figure 9.3 Container transport between Germany and United Kingdom (both directions) via Belgian and Dutch seaports, according to regional origin/destination (x 1000 tonnes), 1992



Source: OTB analysis of NEA data

The presence of large volumes of container freight in the Lower Rhine, combined with the favourable modal split for RSPB in these regions, makes Dormagen the most attractive port of call for RSPB (see also Table 9.3).
RSPB's relative loss of market share when the port of call is Mainz or Germersheim can be explained by its weakened competitive position in these ports with regard to the most important freight transport regions.

Table 9.3 Modal split for container transport between German regions and United Kingdom based on three RSPB ports (in %)

	RSPB ports		
Mode of transport	**Dormagen**	**Mainz**	**Germersheim**
RSPB	74	27	16
Barge/short sea	19	50	58
Road/ferry	7	23	26
Total	100	100	100

9.3.4 Sensitivity analysis

A number of input variables were varied in order to test the sensitivity of the model outcomes to these variables. For instance, the more expensive the commodities being transported, the more attractive it becomes to have them transported faster, and we might expect the market position of the road/ferry option to improve correspondingly. However, the value of the freight turns out to have only a limited influence on the time valuation, and thereby on RSPB's competitive power. Details are shown in Table 9.4, which displays transport time valuations for different product values, logistical costs and transport time savings. It shows that substantial time costs are involved only when considerable time savings can be achieved for high-value freight entailing high logistical costs. If we look for instance at products with the average value of €2,90 per kg (see section 9.3.2), assuming these products would entail high logistical costs (15% of the product value), then a transport time saving of one day (24 hours) would result in a time cost saving of €26,82 per container unit. If a time saving of one day would occur on a transport of products with the same value, but entailing much lower logistical costs (9% of the product value), cost savings would decrease to € 16,09 per container unit. These examples show how fast road/ferry transport could compensate higher transport costs by saving on time costs. However, since the actual differences in transit time between RSPB and the road/ferry option are within the range of 24 – 27 hours (see also Table 9.1), we can conclude that the differences in time cost are rather limited (unless the products are very expensive). RSPB's low transport costs seem to be well able to make up for the fact that its transport times are longer than those offered by the road/ferry option.

Table 9.4 Time cost savings (in euros per 40ft container) for different product values, transport time savings and logistical costs

Logistical costs (% of product value)	9				15			
Transport time savings (hours)	4	8	16	24	4	8	16	24
Product value (euro/kg)								
0.5	0.46	0.92	1.85	2.77	0.77	1.54	3.08	4.62
1	0.92	1.85	3.70	5.55	1.54	3.08	6.16	9.25
2.9	2.68	5.36	10.73	16.09	4.47	8.94	17.88	26.82
6	5.55	11.10	22.19	33.29	9.25	18.49	36.99	55.48
12	11.10	22.19	44.38	66.58	18.49	36.99	73.97	110.96

9.4 Conclusions

The competitive power of the River Sea Push Barge system lies principally in its low transport costs. In cost terms, the system is in a position to compete with both the road/ferry and the barge/short sea transport options. As far as transport times are concerned, the RSPB system also has an edge over the barge/short sea route, since the slightly slower speed of RSPB compared to conventional barges (and, of course, coasters) is more than compensated for by the time saved through not having to tranship in a seaport such as Rotterdam. RSPB remains much slower than the road/ferry option, which is unbeatable in this respect.

With these findings in mind, the RSPB concept should direct its efforts towards market sectors for which the time factor is of less importance; in other words, the market sector currently served by barge/short sea services.

On the basis of the regional distribution of unitized freight volumes, and RSPB's competitive position on the various routes, a port in the Lower Rhine, for instance Dormagen, is the most attractive location for a proposed RSPB port of call. The choice of a port of call in the Lower Rhine has a favourable effect on the comparative transit times offered by the RSPB concept, since the shorter the overall transport time, the greater the comparative time savings achieved by avoiding an intermediate seaport transhipment.

This conclusion is remarkable when one considers that the target market initially envisaged for RSPB was the Middle and Upper Rhine region, in order to develop an alternative to the road/ferry and barge/short sea transport services which so far have no serious competition from the river-sea transport option in these regions.

One of the additional benefits of starting a RSPB transport service on a relatively short haul, e.g. between Hull and Dormagen, is that a reasonably frequent, commercially attractive service (2 or 3 departures per week in both directions) could be maintained with relatively little material investment. Because of a short turnaround time of the services, a very limited number of barges are required. The largest initial investment, the cost of the new push barges themselves, is thereby limited, and this limits the risk involved in starting up an RSPB service.

Dependent on its success the number of services and the systems' geographical scope of operation (ports of call) could be expanded. In addition, new transport corridors with less favourable waterway conditions for conventional coasters could be entered as well, exploiting the technical advantages of the system at the most. Observing the interesting sea-river routes in Europe (see Rissoan, 1994), a potential large market for the RSPB concept exists.

The condition of limited investment costs and associated risks is a very important advantage of the RSPB-concept compared to other technical solutions for integration of inland and short sea shipping, such as sea barge docking and LASH (Lighter Aboard Ship) concepts. In all these concepts barges are taken aboard on sea-going vessels. The large investments in dedicated sea-going vessels, the large transport volumes required and controversial attitudes towards these barge carrier systems, are major explanations why these systems did not really succeed in the past (see also Hilling, 1977). Nevertheless, barge carrier systems, among which the Combined Traffic Carrier Ship/Barge concept (Janssen, 1994 & 1997), still enjoy serious interest. It would be worthwhile to investigate whether the conditions needed to implement this type of river-sea system have been improved by now.

Ultimately, both types of systems – the River-Sea Push Barge system and the barge carrier system – could give a new dimension and great stimulus to the development of intermodal transport in Europe.

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10 Continuous poor profitability in the container trucking industry: is there a way out?

Konings, R., Continuous poor profitability in the container trucking industry: is there a way out? Paper submitted for publication.

Abstract

The functioning of the container trucking industry can be considered somewhat of a paradox: container transport is a booming business and is therefore a growth market for road transport, but in spite of this the trucking industry has great difficulties in operating profitably. Increasing competition of the alternative modes, rail and barge, plays a part, but the major explanation for poor profitability is related to the market structure of the container trucking industry. Its market structure fits to the theoretical model of perfect competition. This model is used to explain and illustrate the behaviour in the container trucking industry. In addition, this model is used to identify clues to improve the profitability of the sector. Promising strategies include offering added value services and increasing the scale of operation.

10.1 Introduction

Since the introduction of the container as a load unit 50 years ago transport of goods in containers has been growing rapidly. Especially in deep sea shipping container transport has assumed large proportions and is now one of the most important shipping industries. As a result container transport has also become a major business in land transportation, in particularly in traffic between seaports and their hinterland. In accommodating this container traffic road transport plays an important role. If we look for instance at major container ports in Northwest Europe, it is a fact that the modal split of inland transport of containers is very much in favour of road transport (Table 10.1) (see also Darch, 2002). The significant role of barge transport in Rotterdam and Antwerp can be explained by the availability of a high-quality waterway network, which is much less developed around the ports of Hamburg and Le Havre. However, the dominant role of road transport is unmistakable.

Table 10.1 Modal split in inland transport of containers in selected major European seaports (x 1000 TEU and %), 2007

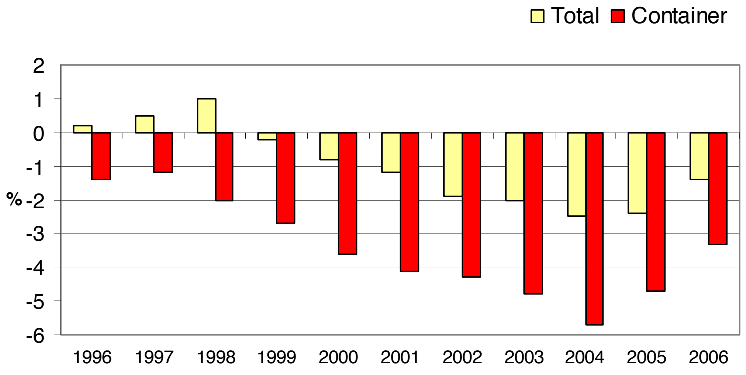
	Rotterdam		Antwerp		Hamburg		Le Havre	
Road	4.800	59	4.431	57	3.468	64	1.623	86
Rail	900	11	775	10	1.830	34	98	5
Barge	2.500	30	2.618	33	92	2	159	9
Total	8.200	100	7.824	100	5.390	100	1.880	100

Source: Port Authority of Rotterdam, Antwerp, Hamburg and Le Havre

The success and the attractiveness of road transport can be attributed to its speed, flexibility, reliability and high service level. Customers generally value the performance of road transport very positively, but this is in contrast with the rather poor economic and social performance of the container trucking industry. If we look at the Dutch container trucking industry, which can serve as a model for the West European trucking industry, it is difficult to make money in this kind of transportation business.

Data regarding the profitability of the container trucking industry show that this industry seems to operate unprofitable for many years. Moreover, the container transport sector also performs much worse than other sectors in the trucking industry.
Figure 10.1 shows the development of profitability in international container trucking, but the results in domestic transportation are comparable. Transport firms have been confronted with substantial increases in costs over the last years, while the development of rates lagged behind, contributing to this poor profitability (Figure 10.2). As a result of bad profitability the number of bankruptcies has been substantial, but surprisingly also many new firms were established. Another observation is that driving time and maximum payload legislation are regularly violated, although this is not a problem of the container trucking industry exclusively. Strong competition is a likely explanation for these observations and seems to arise at two levels: between modes and within the mode of road transport.

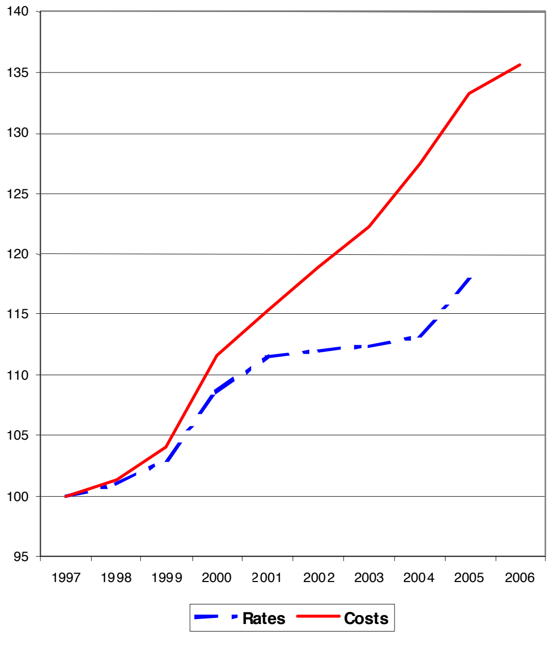
Figure 10.1 **Average profitability* of the container trucking industry and the total industry of Dutch truckers (in international transportation only), 1996 – 2006**



* Profitability is defined as the net annual balance of profit, i.e. firm revenue minus costs and estimated costs (for pay and interest) as a percentage of the firm revenue.

Source: NEA / Transport en Logistiek Nederland (TLN)

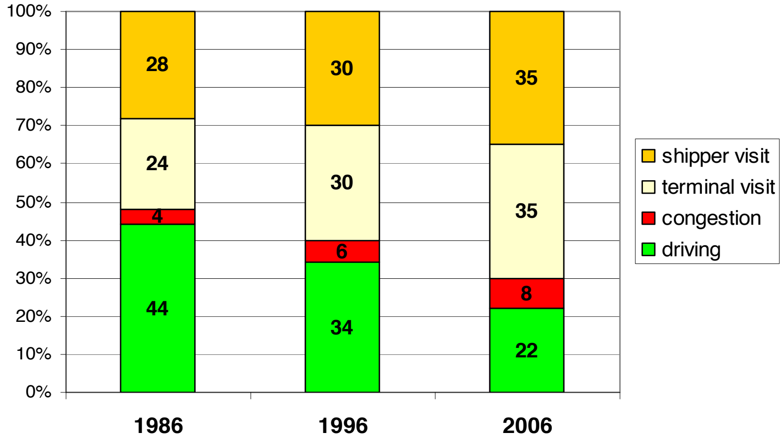
Figure 10.2 **Development of rates and costs in domestic container trucking in The Netherlands (Index, 1997 = 100)**



Source: NEA and Centraal Bureau voor de Statistiek (CBS)

It is beyond doubt that the competition from rail and barge transport has increased during the last 10 years. The expansion and improvement of intermodal transport services has increased the attractiveness of rail transport and, in several places in Europe including The Netherlands, in barge transport as well. The number of inland terminals substantially increased. Consequently, more inland areas have become accessible to intermodal transport and also the frequency of intermodal services increased. The availability of more terminals and higher service frequencies has to some extent mitigated the disadvantage of lower flexibility of intermodal transport. Increasing container transport volumes have enabled new logistic concepts and an increase in scale of operation in barge transport, which have contributed to a further cost reduction of container barge transport. As a result barge transport can nowadays compete with road transport on much more transport relations and on shorter distances.
On the other hand road transport is confronted with increasing fuel costs and congestion on roads and at terminals. Due to congestion road transport becomes more expensive, slower and less reliable. Road congestion in particularly occurs around large cities, such as port cities, and hence typically affects container truckers. However, congestion at the marine terminals due to so many truck visits is also a serious problem. Waiting times caused by traffic jams and related to the (un)loading at premises of shippers and terminals are increasing and this actually means that the business time spent on driving is decreasing. This development is most manifest in domestic transport, where the transport distances are short and consequently non-driving activities anyhow have a relatively large share (Figure 10.3). Especially the increase of congestion at marine terminals is leading to unbearable situations and is a reason for truckers to impose a surcharge to their customers to compensate for these waiting time costs. These circumstances favour the attractiveness of rail and barge transport, although terminal congestion is also an issue for barge transport (Konings, 2007).

Figure 10.3 Average time consumption in domestic container road transport in The Netherlands (in %)



Source: IG&H Management Consultants

Despite the increasing competitiveness of intermodal rail and barge transport and the erosion of the captive market for container road transport there are still many relations offering road transport a comparative advantage over rail and barge transport. Moreover, there is also a complimentary role for container road transport in the pre- and post-truck haulage of intermodal transport. Overlooking the development of container volumes transported by truck the growth of road transport has been impressive. From 2002 tot 2007 the number of containers transported by truck in the hinterland of Rotterdam increased from 1,959,000 to 2,835,000 units, which is a growth of almost 45%. The poor performance in this industry can therefore not be explained by competition from rail and barge alone. Other forces seem at hand and the question arises: what is the role of intramode competition here?

In this paper we will examine the container trucking industry in some more detail in order to reveal the causes for a low profitability and to look for opportunities for improvement. This issue will be discussed in a micro-economic perspective on market behaviour and in the context of the Dutch transport market.

The structure of the paper is as follows. First the features of the container trucking industry are described in more detail in order to explore the market characteristics. Based on a theoretical framework of market behaviour this description is used to define the market structure of the container trucking industry. This theoretical model is used to explain and illustrate the behaviour in the industry as well as to identify clues to improve its profitability. The paper ends with conclusions and perspectives.

10.2 A closer look at the container trucking industry

It is difficult to define the container trucking industry accurately. Registration of trucks in The Netherlands is based on the core business of a firm, but does not exclude transport activities in other submarkets. Particularly in large companies trucks might be used now and then in several markets. Small companies, especially those having just one truck, are most likely to be involved in one submarket only. Due to changes in the way of collecting data on freight transport in The Netherlands the definition of the container trucking industry has been further complicated.

The number of companies that are involved in container transport was estimated at about 1,000 firms in 2006 (Zengerink, 2006), which means about 8% of the total population of Dutch road transport firms. In the nineties the number of container trucking firms has increased substantially. From 1993 to 1998 growth was 30%. However, in the same period the number of firms operating one truck increased by almost 100%. In 1998 about 25% of all firms were one-truck companies (Transport en Logistiek Nederland, 2000). This development can be explained by many ‘real’ new entrants, but also by truck drivers employed at large firms that became so called independent drivers. This means that they started their own transport business. The driving forces for this development have their roots both at the employers’ and the drivers’side. For the employer it can be a way to save on labour costs or at least to make labour costs flexible. He can hire this independent driver to perform part of the transport orders that the driver used to carry out when he still was an employee in that trucking company. For the driver the motivation to become an independent driver is the perspective to have a larger income by hard working, to have more freedom, e.g. in planning his own working hours, and, in times of economic recession, more security of at least keeping a job. It is the combination of these aspects that strongly attract people to this profession. This sounds like a paradox, because of the negative profitability results of the industry. However, if a trucker is willing to work much more hours than a forty-hour week, indeed he can get a substantial income, but this is something that is not reflected in the profitability data. The calculation of these data is based on what is generally considered as an acceptable level of remuneration for labour input.

Although accurate up-to-date and sector-wide data on the number and size of container trucking firms no longer exist, the structure of the Dutch Alliance of Seacontainer Transport companies (Alliantie Zeecontainer Vervoerders: AZV) – an association for container transport truckers – supports the assumption that small-sized firms still dominate this industry. In the AZV-association, counting 300 members, 24% of the companies have a license to operate one vehicle only, i.e. are one-truck companies (Table 10.2).

Table 10.2 Distribution of Dutch container trucking companies (AZV members) by size (in the year 2008)

Number of licenses (= number of truck units)	Number of firms	%
1	73	24
2	23	8
3	13	4
4	11	4
5 to 10	63	21
10 to 20	46	15
20 to 50	50	17
50 to 100	13	4
100 and more	8	3
Total	300	100

Source: Transport en Logistiek Nederland (TLN)

Establishing a new firm in the container trucking industry is relatively simple. A truck and a trailer are the only capital assets needed to start business. Since such equipment can also be leased easily, the capital investments can be modest. Compared to several other road transport businesses container transport does not require a lot of specific knowledge: the focus is on transporting a box rather than cargo that for instance may require specific or careful treatment. In other words, it is rather easy to enter the market.

Looking at the demand side of container transport the main players are container shipping lines, forwarders and shippers. Although these customers are numerous, many of them are large international operating companies, which provide them a strong market position. This holds in particularly for shipping lines and forwarders. These companies also have a strong interest in controlling the logistic chain, including the cost of landside transport services (Konings, 1993).

To summarize, the container trucking market consists of many rather small-sized trucking firms and a relatively great number of large powerful customers. These circumstances provide customers to have a strong bargaining power to obtain low rates. Moreover, the price seems to be the most important distinguishing element in the marketing strategy of a transport firm, because container transport consists of rather uniform services. Adding the fact that a customer can usually switch easily to a transport firm offering a lower rate, this can explain that price competition between firms is fierce and rates and profitability are low.

10.3 A framework for analysis: market theory

According to economic theory behaviour of a group of firms can be explained by market structures (Koutsoyiannis, 1979). Various criteria have been suggested for the classification of markets. Traditionally the basic criteria are the existence and closeness of substitutes (substitutability of products criterion) and the extent to which firms in the industry take into account the reactions of competitors (interdependence criterion). The latter criterion is closely related to the number of firms in the industry and the degree of differentiation of the product. If there are many firms in the industry each one of them will tend to ignore its competitors. If there are few firms each one will be conscious of its interdependence with the others and will take into account their reactions. Bain (1967) has suggested a third criterion for market classification, i.e. the ease of entry in the various markets. If we compare these criteria with the characteristics of the container road transport market, it fits to the theoretical market structure of perfect competition.

The model of perfect competition is based on the following assumptions (Koutsoyiannis, 1979):

Large number of sellers and buyers
The industry or market includes a large number of firms, so that each individual firm, however large, supplies only a small part of the total quantity offered in the market. The buyers are also numerous so that no monopsonistic or oligopolistic power can affect the working of the market. Under these conditions each firm alone cannot affect the price in the market by changing its output, i.e. the selling firm is a price taker.

Product homogeneity
The technical characteristics of the product as well as the services associated with its sale and delivery are identical. There is no way in which a buyer could differentiate among the products of different firms. If the product were differentiated the firm would have some discretion in setting its price. This is ruled out in perfect competition.

Free entry and exit of firms
There is no barrier to entry or exit from the industry. This assumption is supplementary to the assumption of large numbers. If barriers exist the number of firms in the industry may be reduced so that each one of them may acquire power to affect the price in the market.

Profit maximisation
The goal of the firm is profit maximisation. No other goals are pursued.

No government regulation

There is no government intervention in the market: rate-setting, subsidies, rationing of production or demand and so on are ruled out.

Perfect mobility of factors of production

The factors of production are free to move from one firm to another throughout the economy. It is also assumed that workers can move between different jobs, which implies that skills can be learned easily. Finally raw materials and other factors are not monopolised and labour is not unionised. In short, there is perfect competition in the markets of factors of production.

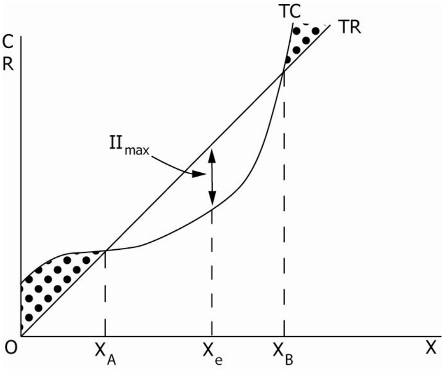
Perfect knowledge

It is assumed that all sellers and buyers have complete knowledge of the conditions in the market. This knowledge not only refers to the prevailing conditions in the current period, but in all future periods as well. Information is free and costless. Under these conditions uncertainty about future developments in the market is ruled out.

Market clearance and equilibrium

The firm aims to maximize its profits i.e. will choose the output level where the difference between total revenues and total costs is greatest. Graphically the level of Xe in Figure 10.4 can represent this. The shape of the total cost curve reflects the inverse shape of the variable cost curve, i.e. the law of variable proportions. The total revenue curve is a straight line through the origin, showing that price is constant at all levels of output, or in other words that the firm is a price-taker.

Figure 10.4 Total revenue (TR) and total cost (TC) curve of a firm in a perfect competitive market



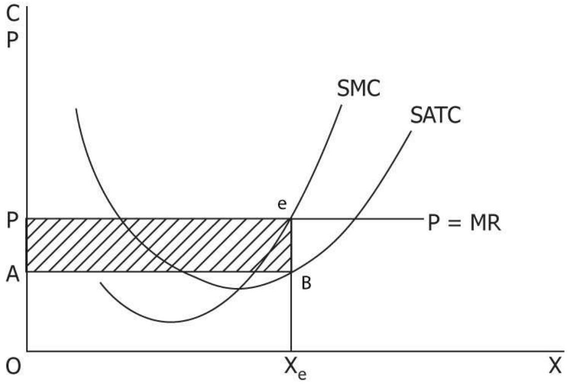
Source: Koutsoyiannis, 1979

Although the total revenue-total-cost approach is simple, it is more convenient and common to study the firms' behaviour in an industry in a marginal cost and marginal revenue approach in which price is included as an explicit variable.

Graphically the marginal cost is the slope of the total cost curve and the marginal cost curve cuts the (short run) average total cost (SATC) curve at its lowest point (Figure 10.5). The marginal cost curve actually also represents the supply curve of the firm.

The marginal revenue is defined as the slope of the total revenue curve. It is constant and equal to the prevailing market price, since all units are sold at the same price. Therefore in perfect competition marginal revenue (MR) = average revenue (AR) = price (P). Since the firm is a price taker and can sell any amount of output at the going market price the average revenue curve is also the demand curve.

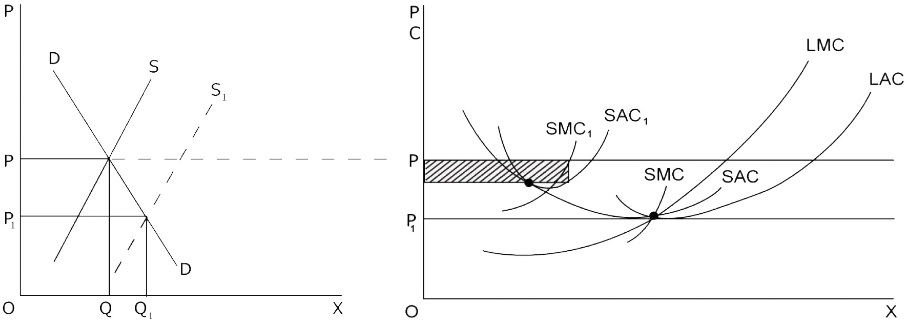
Figure 10.5 Marginal revenue and marginal cost curve of a firm in a perfectly competitive market



Source: Koutsoyiannis, 1979

In this marginal approach the firm is in equilibrium (maximizes its profits) at the level of output defined by the intersection of the marginal cost and marginal revenue curves. In Figure 10.5 the equilibrium (in short run) is at output level Xe, which corresponds here with an excess profit equal to the area of PABe, because the SATC curve is below the price at equilibrium. According to the theory excess profits (or losses) are not sustainable in the long run and the existence of excess profits or losses will cause changes in output (by entry, exit and readjustment of the remaining firms) leading to a long-run equilibrium in which firms just earn normal profits (i.e. a remuneration for use of production factors). In the long run firms are in equilibrium when they have adjusted their plant so as to produce at the minimum point of their long run average cost (LAC) curve, which is tangent (at this point) to the demand curve defined by the market price (Figure 10.6). The industry is in long-run equilibrium when a price is reached at which all firms are in equilibrium.

Figure 10.6 Equilibrium of the firm in the long run



Source: Koutsoyiannis, 1979

According to the perfect competition model container road transport firms would behave in a way that prevents these firms in making excess profits. There are powerful forces that drive market prices to the level where each firm earns no more and no less than a normal rate of return. As a matter of fact this means the lowest price consistent with covering all costs of production. This market price is the result of the interaction of market demand and supply and the container road transport firm is a price taker. There is a powerful competitive struggle in which the firm must respond passively to forces well beyond its control. These predictions of the model seem to correspond very well with empirical observations in the container trucking industry.

These observations also suggest that a container trucking company is operating in a very competitive, dynamic and vulnerable market, in which not only its own behaviour, but also that of all competitors affects the economic performance and profitability. It also means that the profitability of the industry is susceptible to changes in demand and supply characteristics of the industry, which are far beyond control of the individual company.

10.4 Some pitfalls for the profitability of the container trucking industry

Market theory assumes eventually an equilibrium state, but in practice, however, it is not very realistic to assume that the container trucking industry would reach and maintain a state of long-run equilibrium. Constant changes in demand and supply determinants will cause shifts of demand and supply curves. So the market is in a state of constant flux always responding to changes in demand and supply, i.e. actually chasing a new equilibrium point.

We will now discuss some typical examples of circumstances causing these changes and which act as a pitfall for the profitability or even long run existence of container road transport firms.

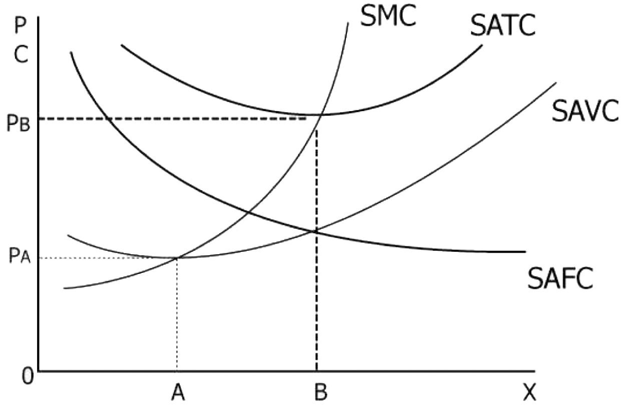
10.4.1 Variable cost-based pricing

One of the pitfalls for profitable operations is variable cost-based pricing, which is often related to cargo flow imbalances, and is a major temptation in transport in general and in container transport in particular. It means that the transport rate is not based on the integral costs, variable and fixed costs, but predominantly on variable costs only. This kind of pricing is often used in roundtrips in which it is unsure if any cargo for the return trip will be available. In order to avoid an ‘empty leg’ in this trip the rate is based on variable cost-based pricing.

Although the economic justification for this form of pricing depends on the ‘correct’ allocation of costs in the double trip – which is a very difficult issue (Rietveld, 1999) – the temptation is big to charge a price that covers only the variable costs and perhaps a small part of the fixed costs. This practice in particularly occurs when the competition is fierce. Of course charging variable cost-based prices can be a strategy to increase or keep market share, but only in the short run. In order to survive in the long run the total costs must be covered. As shown in Figure 10.7 at price level P_A only the variable costs are covered, while P_B reflects the full cost price level. These price levels correspond with the service production levels A en B. Within this interval the price is too low to survive in the long run, but at least some of the fixed costs are covered. The share of fixed costs in the total cost structure determines the size of this interval (Korver *et al*., 1992).

In addition to marketing considerations for such pricing strategies many new entrants in the container trucking industry are not fully aware of these cost principles. The need to replace a truck after several years by a new one that probably is more expensive is sometimes not realized full well. Hence depreciation costs will be incorrect reflected in their rates, and so they are actually pricing in this above-mentioned interval. This means that a trucking company may have a lot of orders, but nevertheless does not earn enough. Such pricing practices have of course a negative impact on the viability of individual firms, but also on the profitability of the total industry, because it fosters ruinous competition.

Figure 10.7 Rates reflecting full cost and variable cost-based pricing



Source: Adapted from Korver *et al*., 1992

10.4.2 Introduction of larger trucks: 3-TEU-truck

In 2000 a pilot started in The Netherlands to operate longer (from 18,75 m to 25,25 m) and/or heavier (from 50 tons to 60 tons) trucks, called Megatruck, Ecocombi or Modular concept. An idea that prompted from the positive experiences in the countries of Sweden and Finland where such long and heavy trucks are in use since 1995.

Due to the larger capacity of these vehicles fewer trucks are needed in transporting cargo and hence such trucks would gain commercial benefits (less trips, higher efficiency) and social benefits (reduction of emission per tonkilometer and congestion). Studies have shown that these large trucks can reduce the number of trips with about 30% and generate a fuel cost saving up to 33%, compared to regular trucks in case they transport an equal amount of freight. A total operating cost reduction was estimated at 25% (Arcadis, 2006).

The positive experiences with these large vehicles were reason to prolong and extend the Dutch pilot in 2004. In 2006 about 100 of these large trucks were running on the Dutch roads, including 28 lorries dedicated for container transport. In November 2007 the pilot was prolonged again for 3 to 5 years. This period is assigned to for experiences with these trucks on a larger scale in order to gain further insights in the merits and demerits of these trucks. After this period a decision on legislation will be taken.

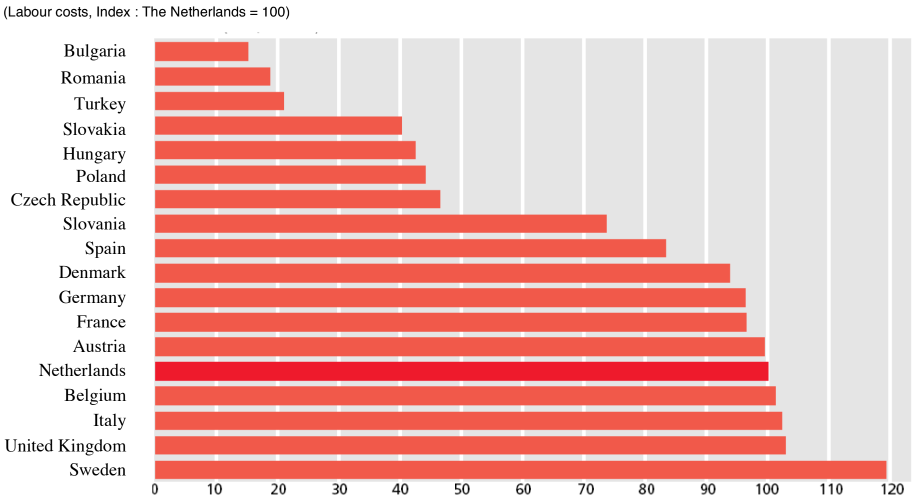
The container loading capacity of these vehicles is 3 TEU instead of 2 TEU of a standard truck and so it enables substantial costs savings. It improves the competitiveness of road transport compared to intermodal transport, but it is likely that it also creates distortions in competitive conditions between container road transport firms. As the number of 3-TEU-trucks in operation increases, customers will be triggered to negotiate lower rates. The experiences in the preliminary pilot have shown that customers count on rate reductions (Nieuwsblad Transport, 2004). Eventually, firms that operate standard trucks are forced to lower their rates or also have to move to 3-TEU-trucks. This would bring the container trucking industry back into a position without an improvement of its profitability, although it might gain some market share from rail and barge transport. How strong these intramode competition effects will be, depend on the conditions imposed on using these 3-TEU-trucks if these vehicles are definitively passed into the market.

10.4.3 Disparities in labour costs at European scale

The perfect competition model implicitly assumes equal conditions for all transport firms regarding the factors of production, i.e. also perfect competition in the markets for production factors. At a European level a variation in labour costs has always existed (in particularly between North and South European countries), but the extension of the European Union (EU) in 2004 with 10 Central and East European countries have brought the issue to the fore and labour cost differences have increased (see Figure 10.8). As a result of mobility of production factors labour costs in the different countries may converge, but this is a very long-term process.

East-European truck drivers earn salaries that are two to three times lower than the wages of their West-European colleagues. This is a serious threat for fair competition, because labour costs have a major share in the cost structure of container transport (about 40%). Foreign container truckers can therefore offer lower rates and oppress the existing West-European trucking companies: or they lose customers or they are forced to lower their rates (Hestens, 2005). The only viable response of West-European firms here seems to be that they also employ cheap foreign truck drivers or flag out their business. Willy Betz, Europe’s largest road transport firm operating about 4000 lorries, was a pioneer in this approach. This strategy is now increasingly copied. Poland in particular is very popular in establishing new offices and to recruit drivers. So far these low cost foreign carriers affect mainly the international transport market. However, when cabotage by firms of these new EU-entrants will be permitted in 2009, also domestic markets may be violated.

Figure 10.8 Labour costs of truck drivers in several European countries, 2006



Source: NEA derived from Transport en Logistiek Nederland (TLN)

It is likely that in the perspective of EU-integration the labour costs of East-European truck drivers will more and more dictate the market conditions for container road transport. That is to say rates will generally be determined by the labour cost level of these countries. Although wages in such countries like Poland are expected to rise, it is believed that large differences with West-European wages will remain for long time, possibly even two decades (Nieuwsblad Transport, 2006). In the meantime other East European countries will emerge as interesting regions to recruit cheap and qualified drivers and part of these workers will then be even more competitive than Polish drivers. Hence it is likely that the industry remains a low profit business, but the players may be quite different: less established West-European firms (exits) and much more new East-European firms (entries).

10.5 Is there a way out?

In order to create sustainable profitability in the industry it is necessary to alter the conditions, which are in the end responsible for a poor profitability. The homogeneous character of services is a major problem, but the low barriers to entry, the limited costs for customers to switch between suppliers and the strong negotiating power of customers also play an important role. In order to change these conditions in favour of the industry a number of actions are conceivable (see also Transport en Logistiek Nederland, 2000).

Product differentiation: specialization or integration of services

Although container transport seems to be a uniform transport product where only price matters for customers – and hence competition seems based on price only – there may be possibilities for transport firms to distinguish them and improve their profitability by offering more specialized or additional services.

Specialization can create a comparative cost advantage and improve the service level. Opportunities for specialization can be found with respect to type of cargo or shipper, equipment (e.g. reefers, 45ft containers) or geographical focus (e.g. drayage operations in intermodal transport).

Offering additional complementary services, however, is probably a more promising strategy as it creates opportunities for additional, more profitable activities. These activities can be logistic services such as stuffing and stripping, storage of empty containers, warehousing and supply chain management. The larger the companies the bigger their assets and know how and the greater the opportunities to offer a wider range of services and more complex logistic services. However, as logistic services are generally more profitable than physical transport activities, large logistic service providers tend to outsource their transport services. This means that the container transport service might remain a lean, low profitable business.

Development of customer relations: to increase switching costs

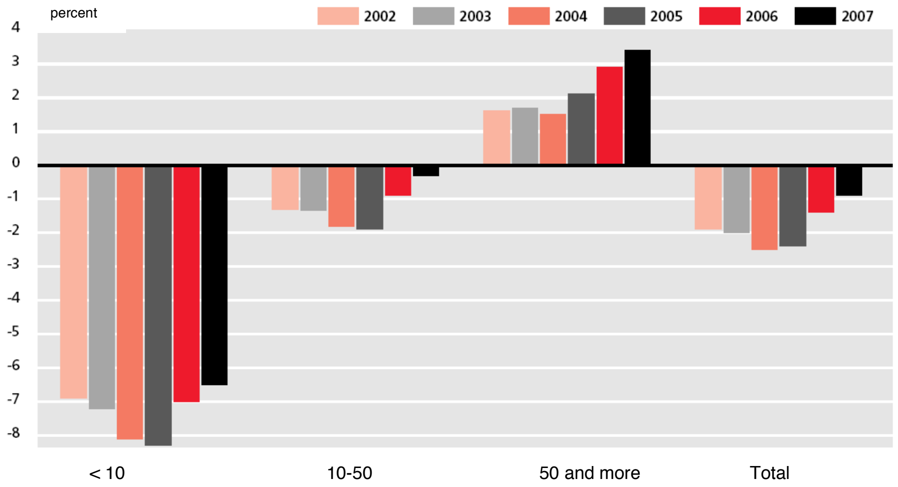
Customers will remain loyal to a supplier if the costs of switching from one supplier to another are higher than the expected benefits. In general switching involves some costs: time and efforts to search, find and select an alternative. In addition, there is a risk of disappointing performances of the new supplier. Moreover, social and emotional aspects are the non-monetary part of the switching costs.

The switching costs in container transport are low, because of the large number of transport firms available and the relative simple kind of services. However, transport firms do have some opportunities to bind customers through increasing these switching costs. One of the options is again an extension of services, which creates a greater dependency, and hence higher switching costs. By offering a complete package of logistic services it also becomes easier to obtain long-term contracts. Last but not least, a good performance of the transport firm supports a sustainable business relation with the customer. He might be less willing to sacrifice this relation for perhaps a temporary cost saving somewhere else achieved by shopping around at competitors. It is clear that social and emotional aspects come into play here: the customer allowing the transport firm to have some profit.

Creating entry barriers: distinguish established from new firms

Price may be the most decisive factor for most of the container transport customers in the selection of transport suppliers, but even then some other quality features cannot be completely ignored, such as punctuality, reliability and flexibility. It is likely that the size of a transport firm can matter regarding a good performance on these quality aspects. A large company has a large truck fleet, can offer more additional services and has better supporting equipment such as information technology facilities, which enables to deal with customer demands in a flexible and efficient way. Moreover, customers may have more confidence in large firms as being a more reliable business partner. Furthermore, the size of the firm can make a difference in obtaining a discount in the purchase of means of production, including buying fuel. These conditions suggest that established firms might benefit from some kind of entry barriers to new firms, in particular since these starting firms are usually small and oftenly one-truck companies. The fact that many one-truck companies are established and remain in business, however, does not support that these barriers are strong. However, as Figure 10.9 shows, in general the profitability of large firms is better than for small firms, but this is mainly explained by revenues generated from other logistic services in which such large companies are usually more involved than small companies. In other words, large firms offering different services have a possibility to cross-subsidize container trucking.

Figure 10.9 Profitability in international road transport by company size (number of trucking units), Dutch truckers, 2002 – 2007*



* Data for 2007: first six months.

Source: NEA, derived from Transport en Logistiek Nederland

Increasing market power: cooperation between transport firms and increasing scale of operation

The strong bargaining power of large customers is something the container trucking industry has to cope with. Through different ways of cooperation such as freight exchange, central planning of trips and joint acquisition firms can operate more efficiently leading to lower costs and higher profitability. In addition, these operational benefits can also be obtained through mergers and business take-overs. The willingness to cooperate however is still limited, but in addition to many small firms there are several large firms aiming to further increase their scale of operation. The size of a firm may help to improve the negotiating position against large customers, particularly in obtaining large contracts. Moreover, it is convenient for customers to have contracts with only a limited number of carriers. However, if the volumes are large, rail and barge transport may become interesting alternatives.

10.6 Conclusions

The functioning of the container trucking industry can be addressed as a paradox: container transport is a booming business and therefore also a growth market for road transport, but despite of this circumstance container trucking firms have great difficulties in operating profitably. Increasing competition of the alternative modes, rail and barge, plays a part, but the major explanation for the bad profitability is related to the market structure of the container trucking industry. As shown in this paper the characteristics and functioning of the container road transport market strongly fit into the market model of perfect competition. This model can explain many aspects of the market clearing process observed in the container road transport business: transport firms are price-takers, transport firms can not earn (excess) profits and there is a lot of mobility in the industry, because of a lack of barriers to entry or exit from the industry.

In theory the perfect competition model leads to an optimal allocation of resources, since the following conditions hold in the long-run equilibrium:

- the output is produced at the minimum feasible costs;
- customers pay the minimum possible price, which just covers the marginal cost of the service;
- firms are used at full capacity in the long run, so that there is no waste of resources;
- firms only earn normal profits.

In practice there are several disturbing factors affecting the demand for and supply of container road transport and also important violations of the assumptions of the perfect competition model that keep the market away from equilibrium state. In theory the number of customers is large and individual customers can not affect the price level (as the demand curve is assumed infinitely elastic). In practice, however, a limited number of large customers, i.e. shipping lines and forwarders, seem able to influence the rate, because of large transport volumes they can offer. This suggests the existence of some market power and confirms the role of a price taker of the transport company. This market power of customers, however, depends on market circumstances, i.e. the total supply of transport capacity. Hence, in general, the assumption that the market price is the result of the interaction between demand and supply is still valid.

The assumption of equal competitive conditions for all transport firms is actually violated. This problem is especially manifest at an European level regarding differences in labour costs of drivers, but it also includes other national differences in conditions. Economic and technical harmonization is a difficult process, but would be needed to stabilize the market.
Product differentiation through offering additional services seems one of the most promising strategies to improve the profitability of the industry, but this requires a certain scale of operations. Large companies do not only have greater opportunities to offer a wider range of services, but such companies per definition have greater market power and can be more

professional than one-man companies. Hence the size of the firm may also help to reduce the threat of new entrants, usually small one-man companies. The better profitability performance of large transport firms in general suggests that the size of a firm matters. This conclusion is not necessarily in contradiction with the trend of outsourcing trucking activities to independent drivers, i.e. one-man companies, since it could indicate that large trucking companies have more interest in operating as a logistic service provider and transport organizer rather than performing the physical transport services, because the latter services are less profitable.

For reasons of low profitability of these physical transport operations there is a strong incentive to recruit cheap truck drivers to be found in East European countries. Large trucking companies have better opportunities to recruit these workers than small-sized firms. Their firm size enables to flag out activities or to establish an office over there.

A result is that the structure of the Dutch container trucking industry will become more and more divided: on the one hand large companies replacing their workforce by cheap East European drivers and on the other hand one-man companies, i.e. independent drivers with a native background. These independent drivers can also operate under favourable conditions, because they have low overhead costs. Moreover, they can benefit from the situation that they are not bound to collective labour agreements for wage-earnings drivers, which give them better income perspectives than their wage-earning colleagues by working more hours. However, European legislation regarding a reduction of drivers' working week is at hand and in this process the different position of wage-earning drivers and independent drivers is under discussion as well. In view of restricting policies with regard to independent drivers it is likely that in the long term the large companies that engage cheap foreign drivers will be more competitive than these independent drivers. Moreover, the workforce of native drivers is also likely to reduce because of the demanding working conditions. Irregular working times, long working weeks, being lengthy away from home, financial uncertainty and stress, make the occupation of truck driver increasingly unattractive.

Some scarcity in the workforce of truck drivers could create opportunities for higher rates and better profitability results, unless this shortage will be filled in by East European drivers. As the interest for the profession of truck driver and the supply of drivers is still large in these countries, this could remain a barrier to improve the profitability in the industry.

The published data regarding the profitability of the industry as a whole indicates at a situation, which is unsustainable. However, it is the behaviour of independent drivers working long hours and of companies cross-subsidizing container hauling and acquiring cheap labour as well as violations of legislation – facts that are not well reflected in this data – which keep the business ongoing. It is an industry of great importance for the economy, but it keeps struggling with many problems.

These problems are not only faced by the container trucking industry in The Netherlands, but by container haulers in many other West European countries as well, who also experience the heavy competition from their East European colleagues. The problems therefore are European-wide and would require policies at a European level. First, there is a strong need to create fair competition conditions for transport services offered by truckers of different nationality. Second, the social malaise in the industry should be reduced. Only if the attractiveness and quality of the profession of trucker can be raised this can offer perspectives for an industry that has sufficient capacity and quality to satisfy the needs of the economy.

The social malaise, as explained in this paper, is caused to a great extent by socially unacceptable labour conditions (poor wages, long working hours, irregular working times, bad social insurance, etc.) for truck drivers in mainly East European countries. The way out here has to be found in enforcing legislation which leads to an improvement of labour conditions and further harmonization of these conditions between countries. This can and should be carried out at the European commission level. To be really effective, these policy measures should, however, also include strong control of the regulations.

Acknowledgement
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11 Summary

11.1 Research question, scope and approach of the thesis

Over the last decades transport has been growing rapidly. On the one hand this is a result of economic growth, but on the other hand the increase in transport services with low costs and attractive service frequencies have also enabled economic growth. Despite its economic importance, the growth of freight transport has also shown serious detriments. It has resulted in an increasing modal share of road transport and, although the vital role of this transport mode is beyond dispute, its contributions to traffic congestion, polluting emissions and unsafety have caused increasing concerns. In view of forecasted growth of freight transport and the need for a sustainable transport development there is a strong motivation to change the current transport system. In addition to improving the sustainability of the road transport sector the possibilities to use alternative transport modes more extensively – in particular rail and inland waterway transport –must be considered, given their transport capacity, safety performance and their features of potentially more energy-efficient and less-polluting means of transport. This thesis addresses the more prominent role that inland waterway transport could play in accommodating surface transport.

Traditionally, inland shipping has had a particularly strong position in transport of bulk goods, both in transport of goods between seaports and their hinterlands and in other transport relations which fit to the typical characteristics of inland shipping. These beneficial conditions for inland shipping consist of transport of large quantities of goods between transport origins and destinations that are located near a water site, where vessels can directly (un)load at shippers and consignees, avoiding a relatively expensive transhipment of cargo to other modes, i.e. road transport, as well as the additional costs of a truck trip between vessel and shipper and consignee. In these circumstances inland shipping is a very cost-effective choice, but in view of the relatively low density of the waterway network the number of these favourable relations is limited.

Moreover, transport of bulk goods has not been a real growth market in the last decades and is not expected to have significant importance in future freight transport growth. There is an on-going trend in the general composition of cargo towards types of goods that have historically less affinity with inland waterway transport. Economic structural changes have led to a faster growth of more highly processed goods rather than raw materials, i.e. bulk goods. On top of this shift between freight categories, in many industries new logistical concepts, changing customer demands and the influence of Internet have resulted in smaller as well as more frequent consignments of goods. These developments have strongly favoured and increased the role of road transport in the total transport system at the cost of inland shipping and as a matter of fact also to the detriment of rail transport.

To regain market share inland shipping needs to play a role in the transport market for semi-finished and finished products and needs to offer transport services which satisfy customers' needs. The increasing role of the container in transporting these products has been an important enabler to enter this market of highly processed goods.

The use of these load units has reduced the handicap of limited network coverage in traditional inland shipping, i.e. the need for time-consuming and costly transhipment, and made it possible to combine the benefits of barge transport with the advantages of road transport, i.e. its high flexibility and accessibility to collect and distribute load units. This way of freight transport, using load units and a combination of modes, has emerged into a new and promising transport market for inland shipping, which is known as intermodal barge transport. Currently, inland shipping is involved in transport of containers, but with varying success. The present role of intermodal barge transport reveals that the barge transport volumes are still concentrated in a rather limited number of waterway routes and in very specific transport chains: container barge transport is predominantly a *hinterland transport system* focused on the land leg of *maritime container traffic*. In this particular role the development of intermodal barge transport is important to maintain and improve the hinterland accessibility of seaports. However, to gain significant market share in surface transport in Europe the applications of intermodal barge transport should also expand beyond the scope of a hinterland transport system.

Considering the potential contribution of inland waterway transport to more sustainable freight transport, its strategic importance for transporting containers into the hinterland of seaports and the very limited possibilities for market expansion by traditional barge transport, there is a great challenge to expand its role in the intermodal freight transport market. Based on these observations the central research question in this thesis is as follows:

What are the opportunities and conditions to increase the market share of intermodal barge transport in Northwest Europe?

In answering this research question the aim is to improve the understanding of the intermodal barge transport system, to analyse its performance and to provide recommendations for practitioners and policy makers to improve the competitiveness of this system in comparison with road-only transport.

Increasing the market share of intermodal barge transport can be achieved by 1) improving its competitiveness in existing markets, i.e. the current transport services in the market of container hinterland transport, 2) penetration of barge transport in new geographical markets, i.e. expanding the geographical scope of container barge hinterland transport and 3) opening up the market of continental intermodal barge transport.

In order to increase competitiveness in existing markets and to develop into new market areas the cost of intermodal barge transport should be reduced and/or the quality of services improved. Since intermodal barge transport is a chain process, consisting of barge services, transhipments at terminals and pre- and post truck haulage operations, these different processes should be part of the analysis. Barge service networks and terminals form the core of an intermodal barge transport system and its performance, but the pre- and post truck haulage will also contribute to the competitiveness of the intermodal barge transport system. Moreover, its competitiveness is ultimately also related to performances of its competitors, the road transport sector in particular.

These considerations give cause to elaborate the central research question along three main issues:

1. Network design.
2. Nodes.
3. Competitiveness in chains.

For each of these issues a specific research question has been formulated that has been addressed through papers, since this thesis consists of a collection of research papers.

Although the thesis is elaborated along these main issues it aims for an integrative and broader approach regarding the performance of the intermodal barge transport chain. It addresses the relations between the performances of the links in the intermodal barge transport chain and their meaning for the competitiveness to other modes. As such, this thesis research builds upon the work that was carried out in the European Research project *Terminals and Networks* (TERMINET) in the period 1997 to 2000 and was focussed on innovative terminals for the exchange of intermodal load units and their performances, and on the bundling of flows through the network.

From a methodological point of view the thesis can be defined as a system analysis of intermodal barge transport. The system here consists of the elements that enable intermodal barge transport operations, i.e. an infrastructural network of links and nodes and transport units (barges and trucks) to move containers along the links through nodes (terminals) from/to shippers/consignees. In other words, it covers the three chain activities of barge transport, transhipment and truck haulage from an *operations perspective* and considers their relevance for the improvement of the performances of the intermodal barge transport system and its competitiveness to other modes.

From a geographical perspective the thesis addresses the development of intermodal barge transport in Northwest Europe.

11.2 Summary of results and conclusions

In the elaboration of the central research question three main working lines were defined as the key issues to be investigated: network design, nodes and chain competitiveness. This section describes the specific research questions formulated for these issues, summarizes the main research results regarding each question and provides the major conclusions.

Network design

Research question 1: *What are the major determinants for the performance of intermodal barge service networks and which kinds of networks are most promising to increase the market share of intermodal barge transport?*

This question is about the factors that influence the costs and quality performance of container barge services. The hypothesis is that the cost and quality of the barge transport services are closely related to the network operations within which these services run. A network is here defined as a service network, which can be considered as the production model of transport services. It expresses how transport services are operated, scheduled and routed. Therefore network design is concerned with finding these service networks that offer the best performances. Chapter 2, 3 and 4 addressed this research issue of network design.

A conceptual model for barge network design was developed. This model describes the design variables for barge networks and shows their relation to the performance indicators of intermodal barge transport from a barge operators' and shippers' perspective. The model shows that the vessel size (scale of operation) and the circulation time of a vessel are the major factors influencing the cost and quality performance, i.e. the frequency, transit time and reliability, of barge transport services, and are decision variables that result from a service network design.

The vessel size evidently has a direct impact on the cost performance, but the transport volume plays an important role for the choice of vessel size. However, given a certain transport volume it also has meaning for the frequency of services. Theoretically there is a trade-off between possible vessel size and transport frequency for a certain available transport volume, but market requirements have to be taken into account. Since shippers wish to have sufficient sailings per week a certain minimum frequency of services needs to be offered. The shorter the distance is the higher the required frequency usually is. Related to that, if transport volumes increase often first the number of sailings will be increased and later on the size of the vessel will be increased. Moreover, the choice of the vessel size is not only determined by these transport operational considerations, but can also be influenced by limitations that arise from characteristics of the waterways.

The circulation time, defined as the time between the departure of a barge at a terminal and the following departure of the same barge from that terminal, is the other main factor determining the cost and the quality performance of barge transport. The circulation time of vessels is an indicator for the utilization of vessels. If more roundtrips can be made within the same period of time, the fixed costs are spread out over more transport services, therefore costs per load unit decrease. Since fixed costs are a major cost component in barge transport, this is an important factor in reducing costs. On the other hand the circulation time is directly influencing the transit time of barge services. If the circulation time is shorter, the transport time of a barge service may also reduce, which means an improvement of the quality of the service for the shipper/consignee.

The relation between the circulation time and sailing schedule of a barge service plays a role for the reliability of barge services. There is a preference for circulation times, which are a multiple of twenty-four hours, in order to keep regular sailing schedules i.e. the same departure time for every service. Circulation times usually include some idle time for barges to absorb possible delays and to keep the multiple of a twenty-four hour pattern. The way in which a sailing schedule incorporates possible idle time of barges in a circulation time determines the reliability of barge services.

The circulation time of a vessel is determined by 1) the sailing time, being a function of the transport distance and the sailing speed, which is dependent on the characteristics of the waterways, 2) other qualities of the waterways, i.e. the presence of locks and bridges, in case bridge openings are needed to pass through, since these objects affect the sailing time, and 3) the duration time at terminals, which consists of terminal handling time and terminal waiting time. Here the number of terminals to visit also comes into play. These decisions regarding the locations and number of terminals to call with a barge service as well as the decisions to link different barge services are the bottom line of barge network design. For example, the choice to develop point-to-point services instead of line services will have a direct impact on the circulation time, but it also touches upon the decision about the vessel size.

In other words, the scale of operation and the circulation time of a vessel are not independent decision variables for a barge operator but are also interrelated. Increasing the size of a vessel will increase the total loading/unloading time and therefore a large vessel will spend a greater proportion of time at the terminals. This may especially arise when more terminals need to be served in order to get the larger vessel filled. The circulation time will increase and it might become unfavourable to maintain an efficient sailing schedule. As a consequence, the number of possible roundtrips may decrease, which would have a negative effect on the transport costs per load unit.

The relations between the variables in this conceptual model seem simple, but there are several interdependencies which make it more complex. Firstly, trade-offs exist between the cost and quality of barge transport services, which are the result of a relation between the vessel size and the circulation time of vessels. Secondly, the decisions about vessel size and circulation time are the result of service network design, but are also influenced by the transport market – to be characterized by transport volume and distance – and the waterway infrastructure reflected by the dimensions and quality of waterways, i.e. width and depth of waterways and the presence of locks and too low bridges, that need to be opened to pass through. Basically, the decisions on network design are conditioned by the characteristics of the transport market and the waterway infrastructure.

These conclusions support the hypothesis that the cost and quality of barge transport services are dependent on the network operations in which they run, but also confirm that the type of barge services that could be best implemented in order to capture market share are dependent on the characteristics of the transport market as well as the waterway infrastructure. On the one hand, markets with concentrated large transport flows will require different network operations than markets with dispersed small flows. On the other hand, the quality of the waterways can be a decision factor for the routing of vessels in network operations, but evidently also for the choice of the vessel size.

In chapter 2 this conceptual model has been empirically applied in a case study of hinterland transport between the seaport of Rotterdam and Duisburg in Germany. It demonstrated the potential improvement in the performance of barge transport services as a result of revising the service network from line services to point-to-point services.

In chapter 3 the specific role of the characteristics of the waterway infrastructure for the network design has been elaborated and empirically tested. In order to develop container barge transport on small waterway, this chapter addressed the option of developing the trunk-feeder service as a promising type of service network to improve existing barge services on small waterways or to open up new geographical markets for container barge transport.

Instead of offering direct barge services to destinations along small waterways, the idea is to split the service into a feeder service part that is implemented on the small waterway(s) and connects to the trunk service part, which is offered at a large(r) waterway.

The analysis showed that substituting a direct barge service into a trunk-feeder service can improve the cost-quality performance of barge services to destinations along small waterways, because it enables a better utilization of vessels. However, there are many factors, which influence the network performance. The network configuration, i.e. the length of the feeder route related to the length of the trunk route, is an important factor. Moreover, in addition to available transport volumes, there are many other external conditions (e.g. sailing speed regulations, presence of locks, height restrictions under bridges, terminal performance) and operational decisions (e.g. type of vessels used, service frequency and schedule, possibility of board-to-board transhipment) that influence the performance. Therefore the evaluation of the commercial feasibility of a trunk-feeder service to develop container barge transport on a small waterway requires a tailor-made approach.

Chapter 4 focussed on another barge service network as an alternative for the commonly used line services and point-to-point services. It addressed the conditions and implications for operating hub-and-spoke service networks. The general features of hub-and-spoke networks were used as a framework to explore the feasibility of hub-and-spoke networks in container barge transport. It was found that the typical characteristics of hub-and-spoke networks could be highly supportive to enable market expansion for container barge transport. Firstly, its operational characteristics make this network very suitable to implement new services between origin-destination pairs for which the transport flow is too small to run a direct (point-to-point) barge service. Secondly, because of its ‘multi-directed’ (star-shaped) network structure this network would be pre-eminently suitable to enhance the geographical coverage of transport services.

The major critical conditions for the viability of hub-and-spoke barge networks are the length of the spoke routes and efficient, reliable and fast exchange of containers in the hub in order to limit the costs of additional container handlings and to limit additional transit time of containers. The additional handling costs might be compensated by an improved cost performance on the links of the network, which can be easier achieved on longer sailing distances. Limiting additional transit time of containers requires a fast handling process in the hub, but also that the sailing schedules of vessels from different spokes are attuned. The disadvantage of additional transit time, however, might be limited, because its relevance depends on the relative loss of time compared to the total transit time as well as the time-sensitivity of the goods that are transported.

To conclude, the answer to the question which barge service networks are most promising to increase the market share depends on the characteristics of the transport market and the waterway infrastructure. The preferred service network should be evaluated according to the specific market and infrastructural conditions. On the one hand, markets with concentrated large transport flows will require different network operations than markets with dispersed small flows. On the other hand, the quality of the waterways can be a decisive factor for the routing of vessels in network operations, but evidently also for the choice of the vessel size.

If the transport volume between an origin – destination pair is large enough to offer direct frequent services, then the point-to-point service is the ideal network configuration. Since it consists of direct connections without intermediate stops, it can offer the best performances, i.e. short transit time, high reliability and low costs, because there is no intermediate transhipment. If the transport volume is too small for a point-to-point service the line services can be an option, but having the disadvantage of a larger transit time, and possible lower reliability, because more terminals have to be visited to load and unload containers. Although each container is loaded and unloaded one time the barge chain costs (shipping and transhipment costs) are in principle also higher in this type of services due to the larger circulation time of the vessel. Alternatively more complex service networks can be considered in which intermediate transhipment is needed such as the trunk-feeder network and the hub-and-spoke network as we have discussed here.

The fact that these networks basically consist of services involving an intermediate transhipment offers a major advantage. It enables the implementation of point-to-point services between the hub-and-spoke terminals in the hub-and-spoke network and in the feeder part and possibly also in the trunk part of the trunk-feeder network, which can keep the circulation time of the vessels relatively small in order to make the vessel more productive, i.e. achieving economies of density, and, moreover, the vessel size can be fully adapted to the waterway dimensions of the specific spokes and the trunk and feeder routes, i.e. achieving economies of scale.

The major disadvantage, however, is the need for intermediate transhipment which involves additional costs and time. Consequently, this will increase the transit time and will endanger reliability of services. The additional costs of these handlings, however, are supposed to be compensated by the improved cost performances on the links of the network. This can only be achieved if the length of the routes (spokes and trunk and feeder) is sufficiently large to enable low cost operations and the transport volume is large enough to offer an acceptable service frequency.

In general the trunk feeder service seems the most promising type of network to expand the geographical scope of the container hinterland transport market, while the hub-and-spoke network would be pre-eminently suited to capture new geographical markets, in particular the market for continental cargo.

The operational requirements for hub-and-spoke networks suggest that such a network can only be developed on a large geographical scale, i.e. at international European level. Moreover, considering the position and navigational conditions of waterways in Northwest Europe there are not many places where such networks could be developed.

The most promising strategy to develop hub-and-spoke networks would be that the well-developed barge hinterland services become a part of a hub-and-spoke network. This provides a base cargo load to develop (new) spoke lines in which maritime and continental cargo flows can be bundled. This bundling of flows, which enables cost-efficient and frequent services, can be a self-reinforcing process.

Nodes

Research question 2: *What is the role of terminals in the cost and quality performance of intermodal barge transport and how can terminals contribute to a better performance?*

This question on the one hand addresses the issue of transhipment costs and possibilities to reduce these costs, as these costs seem inherent to the characteristics of intermodal transport, while on the other hand it refers to opportunities of quality improvement in exploring possible additional functions of terminals. In elaborating this question we can deal with the role and position of an individual terminal, but the issue can also be addressed at a broader spatial level. In that case it is more appropriate to speak about nodes.

The elaboration of this issue started with an analysis of the possibilities to improve the handling of barges in the port of Rotterdam (chapter 5). The bottom line of this problem of barge handling in the seaport is that barges have to call many terminals in the port when they visit the port of Rotterdam. This involves a lot of time which could be used more productively, for instance for sailing, and it leads to congestion and waiting times at terminals, because many barges call at the same terminal and therefore causing delays when visiting the port. Consequently, barge operators need relatively large margins in their sailing schedules when planning these terminal visits to ensure reliable transport. Altogether the duration time in the port is relatively long, which has a negative influence on the transit time and total cost of barge services. As a result the poor quality of handling barges in the port has an adverse effect on the competitiveness of container barge services to the hinterland.

The characteristics of this problem gave cause to deal here with the node at the geographical level of the port area of Rotterdam and to address the possible solution for improving the handling of barges through a reorganisation of the barge services. This idea consists of splitting existing services into a trunk line operation in the hinterland and collection/distribution operations in the seaport.

Three of these revised network designs were proposed and have been empirically evaluated on their economic feasibility. From these analyses the main conclusion could be drawn that the trunk line – collection/distribution services can improve the competitiveness of barge hinterland transport, but their effectiveness depend on several conditions. These conditions first of all are related to the design and organisation of collection/distribution transport. However, the characteristics of the trunk line operation in the hinterland are also relevant, since the distances in the hinterland services and the rates of these services appear distinctive factors.

Chapter 6 zooms in at the level of the terminal processes and the performance of terminals. It focuses on the future requirements and opportunities of barge terminals to improve their performance and to contribute to the competitiveness of intermodal barge transport. It argues that new terminal and container handling concepts can contribute to making container barge transport more attractive and discusses some concrete study designs to illustrate their potential.

Chapter 7 is devoted to a concept, which addresses the importance of a spatial and functional integration of container-handling activities with the storage and collection and distribution of goods as a way to establish a high-quality intermodal transport solution. In this explorative research it is argued that the contribution of a terminal to the performance of intermodal transport can be increased through acting as a key element within a cargo traffic centre rather than just a transhipment facility between different modes. A major element in this concept is the implementation of an internal transport system which is not only employed for terminal handling processes, including transport to container storage areas (stacks), but also to move containers between the terminal and container cargo receiving and cargo shipping companies established at a site near the container terminal. This internal transport system is the mean to establish the functional integration of these activities. The spatial integration of these handling, storage and container cargo business is also an important element, because the mutual proximity of these activities supports a more efficient organisation of pre- and post-haulage in the intermodal chain, as has been further elaborated in research question 3. This concept of integrated centres for transhipment confirms the possible contribution of innovative terminal concepts to increase the attractiveness of intermodal transport.

To recapitulate these results into major conclusions, the first conclusion is that terminals do play an important role in the cost and quality performance of intermodal barge transport. Terminal handling has a significant share in the costs of the total barge transport chain. This holds for barge handling at inland terminals, but even more for barge handling in seaports. The second conclusion is that the role of the terminals should be part of an analysis of barge service networks. The characteristics and functionality of barge terminals can be a pre-condition to enable the development of innovative barge service networks to increase market share in existing markets for container barge hinterland transport or to open up new geographical markets in hinterland transport and the continental transport market. However, on the opposite, the performance of terminals can also be influenced by the features of the barge service networks. The analysis in chapter 5 regarding the handling of barges in the port of Rotterdam, showed that a revised barge network design for hinterland transport services can support an improvement of barge handling in the seaport. Hence there is a mutual dependence between the performance of service networks and terminals.

As regards the contribution of terminals to the performance of intermodal barge transport a differentiated approach is needed in developing new terminal and handling concepts. The major drivers for this differentiated approach are the container volumes to be handled and the position of the terminal in the network. Basically there are three ‘locations’ in the network were tailor-made barge handling innovations are needed: 1) in the seaport, 2) in the capillaries of the waterway network and 3) in more complex service networks, i.e. to support hub-and-spoke networks.

Chain competitiveness

Research question 3: *What are opportunities and threats to improve the competitiveness of intermodal barge transport at transport chain level?*

In the elaboration of this research question the possible contribution of barge service networks and terminals to improve the competitiveness of intermodal barge transport are put in a broader perspective. Ultimately the performance of the whole transport chain plays a decisive role for the competitiveness of intermodal barge transport compared to road-only transport. This perspective was elaborated in chapter 8 and 9.

Chapter 8 examined at which geographical level intermodal transport services can be competitive to road-only transport. It discusses the possible degree of market coverage by intermodal transport, which touches on the issues of the density (intricate structure) of intermodal networks, the scale of intermodal terminals and the size of the terminal service areas for pre- and post truck haulage. Since pre- and post-haulage by truck is usually unavoidable, due to the limited coverage of the network of waterways, it is important to understand the relevance of these haul operations for the performance of the intermodal barge transport chain. In discussing the relations between network, terminal and pre- and post truck haulage operations the chapter deals with the question to what extent synergies or trade offs between these chain activities can emerge. The results of the discussion in this chapter suggest that a blueprint of the geographical level at which intermodal transport can be competitive to road-only transport can not be given. The characteristics of the transport landscape, mainly defined by transport volumes and the origin and destinations of cargo flows, are crucial factors that determine the conditions to offer attractive intermodal barge transport services. There is the challenge to fit the barge service network to the transport landscape. The discussion also confirms the major role of pre- and post-truck haulage for the total cost performance of intermodal barge transport. Major cost improvements in these operations could be achieved through improving the organisation of pre- and post truck haulage trips (i.e. combining loaded trips), but the possibility for this appears to be dependent also on the transport landscape characteristics: the transport volume, the imbalance of inbound and outbound cargo flows passing the terminal as well as the location of customers relative to the terminal and to each other, i.e. the pattern of customer location and customer density. Since larger volumes at terminals may result in lower terminal handling rates, this enables, ceteris paribus the total intermodal chain costs, to increase the distances in pre- and post truck haulage. As a result the service area of a terminal can be increased which enables to combine more trips favourably. In this way there is a mutual dependence in the cost performance of terminals and pre- and post truck haulage.

Many of the general notions on transport chain performance discussed in chapter 8 are elaborated and applied in chapter 9 to a special intermodal barge transport concept, i.e. a river sea push barge system. The competitiveness of this system to different other modes, including road transport, has been examined for envisaged services on the United Kingdom – Germany corridor. To this end a model was developed that can be used as a tool to determine the optimal choice of ports to serve. The model considered the transport quality of services and available transport volumes collectively in order to determine the most interesting transport services of such a river sea push barge system. Based on the conclusion that such a service could be best developed on a relatively short distance, in order to achieve the greatest comparative time savings as a result of avoiding an intermediate seaport transhipment, the analysis confirmed that a short circulation time of vessels is a crucial factor for performance of intermodal barge transport, both in terms of costs and transit time.

In general the competitiveness of the intermodal barge transport system will not only be determined by its own performances but by the performances of other modes as well. Other modes, such as road transport, are also continuously aiming to improve their performance to gain market share from the competitive modes. From this perspective chapter 10 investigated the low level of price setting in the container trucking industry, which – although an external factor for the barge transport industry – is an important issue for the competitiveness of intermodal barge transport. In this analysis it was found that the market structure of the container trucking industry fits to the theoretical model of perfect competition. According to this model trucking companies have great difficulty to operate profitable and due to the competitive forces in the market the price of transport services is inclined to be at the cost level, or even below this level. Although the trucking industry has been confronted in the last decade with serious cost increases, e.g. fuel costs and road taxes such as the Maut in Germany, the sector has well been able to absorb these costs through operating more productive, and hence keeping the transport rates at a relatively low level and so contributing to the competitiveness of road-only transport. Part of this success of road-only transport can also be attributed to its flexibility, both in terms of accessibility and ability to respond instantly to changing customer requests, which makes this sector also less vulnerable to changing market circumstances compared to barge transport. Moreover, barge transport may also be vulnerable to impediments in navigation (low or high water levels or ice formation), which demand for backup transport provisions, i.e. road or rail transport. This kind of flexibility is needed to guarantee the reliability of barge transport.

The major conclusion that could be drawn from this part of the thesis research is that the chain perspective is crucial for the performance of intermodal barge transport and its competitiveness to other modes. There are opportunities to achieve synergy between the different links of the intermodal barge transport chain. These opportunities do not only relate to organisational improvements in the chain, but also have a strong spatial dimension, that is to say, spatial planning could also really contribute to the competitiveness of intermodal barge transport. However, its success to improve its competitiveness to its main competing mode, i.e. road transport, will also strongly depend on the performance development of the road transport sector that seems to be confronted increasingly with disablers to improve its performance. However, since pre- and post truck haulage is an almost inevitable part of intermodal barge transport a deterioration of the performance in road transport can also affect the relative performance of intermodal barge transport.

11.3 Implications for policy

In this thesis a number of development strategies have been proposed to improve the cost and quality performance of the intermodal barge transport system and to increase its market share. The role of transport policies in realising these strategies can not be neglected. Four policy topics deserve special attention here.

First, upgrading the quality of the waterways – including improvement of their interconnectivity and interoperability – can be addressed as a major policy task. In order to develop new intermodal barge services and opening up new geographical markets an integrated waterway network at European level is needed. Since the current waterways structure rather consists of four large corridors[32] than a network, it can be stated that some major missing links between these corridors should be realised, i.e. the Rhone-Saone – Mosel link, the Elbe-Oder – Danube link and the Twente – Mittelland canal link. Such strategic investments have to be initiated at EU-level, but the current European policy on waterway infrastructure in the framework of the Trans-European Transport Network program (TEN-T) is focussed on upgrading links in the existing corridors, i.e. the construction of the Seine-Nordcanal and resolving bottlenecks in the Rhine/Meuse-Main-Danube inland waterway axis.

Other measures to improve the quality of waterways should include the extension of waterways and increasing or at least retaining the permitted draught, but of greater importance for container barge transport is the renovation of locks and bridges and the co-ordination of the opening regimes of locks and bridges. Evidently these actions will be most effective when

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[32] *Rhine corridor*: the Rhine basin and its tributaries, covering parts of The Netherlands, the western part of Germany, parts of Belgium, Luxemburg, France and Switzerland; *East-West corridor*: covering parts of North Germany, Poland and Czech Republic; *Danube-corridor*: the Danube basin covering Southeast Germany, Austria, Slovakia, Hungary, Romania and Bulgaria; *North-South corridor*: covering parts of The Netherlands, Belgium and France.

implemented at the level of an entire corridor. These policy actions are carried out by national, regional and local public authorities, but at a rather slow pace. The Dutch transport consultancy NEA[33] observed that from 1995 to 2005 only 4% of the investments on transport infrastructure were spent for waterway transport, of which 3% in ports and 1% on inland waterways, while freight volumes on inland waterways increased with more than 10%. On the other hand the investments in roads counted for 63% of the total budget, while railways had a share of 33%. Actually, maintenance gets priority over new investments, but due to limited budgets there are arrears in maintenance of waterways, including the locks and bridges. Since the maintenance expenditures are generally in favour of large waterways the conditions of the small waterways leave a lot to be desired. To increase or even to preserve the geographical scope of intermodal barge transport this maintenance arrear must be made up.

Secondly, in view of the opportunities that small waterways can offer to increase the market area of intermodal barge transport, it is a precondition that small vessels remain a part of the inland vessel fleet and conditions to operate small vessels are favourable. To address the need for policy here, the major branch organisations of inland waterway transport in The Netherlands submitted an action plan to their national government at the end of 2008, covering a wide range of actions (including improved labour, fiscal and social regulations, promotion of new building of small vessels and image campaigns).

Thirdly, there can be several policy actions defined regarding the function and position of the nodes in the intermodal barge transport system. Governments can have a role in creating the pre-conditions for inland port development and multimodal transhipment facilities. In this context there is a need for spatial planning policies which support the development of business areas which have direct access to inland waterways. This enables important savings in the costs of pre- and post truck haulage and moreover also creates favourable conditions to develop and operate transhipment facilities to serve companies at these business areas.

Fourthly, there is the issue of the internalisation of the external costs of transport, which is a subject that raises intense political discussion, but is likely to become reality sooner or later. This action may affect the competitiveness of barge transport to other modes, road transport in particular. A major step into this direction has been the formulation of European external cost regulation that has been agreed by the European Parliament. This regulation focuses on charging the external costs of road transport, i.e. emissions and noise production, to the road transport companies, and eventually possibly also the costs of congestion. This will make road transport inevitably more expensive. The plans for charging the other modes for external costs are less elaborated. So far barge transport seems only forced to switch to more expensive, environmental-friendly fuel. How this policy process of internalisation of external costs will in the end effect the competitiveness of barge transport remains to be seen. Except for political considerations much will depend also on the performances of the barge transport sector in developing itself into a more environmental-friendly mode. This is, however, not a self-evident process, but is mainly driven by standards laid down by governments. Due to the long life span of vessels the barge transport sector can less easy and quickly implement new environmental-friendly technologies into its fleet compared to the road transport sector. Moreover, due to uncertainty about future standards for the environmental performance of transport means, this inflexibility to adapt to changing circumstances can be a disadvantage for barge transport.

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[33] NEA, 2009, Do modes get what they deserve?, Rijswijk.

11.4 Directions for further research

In aiming to improve the performance of the intermodal barge transport system many different issues play a part of which only a few could be addressed in this thesis. The research focussed on the processes of the intermodal barge transport chains from an operations perspective and their relevance for the improvement of the performance of the intermodal barge transport system and its competitiveness to other modes. Without doubt valuable topics for further research can be defined on a wide range of themes which influence the performance and competitiveness of intermodal barge transport, but as a follow-up of the issues addressed in this thesis three directions for further research are worth to highlight here.

The first direction, continuing the research where it ended now, is the further investigation of the hub-and-spoke network for intermodal barge transport. Considering the potential great value of this type of network to accomplish an increase in the market share of intermodal barge transport, as shown in chapter 4 of this thesis, further research is needed to support eventually its implementation. The arguments mentioned in favour of the hub-and-spoke network were based on the results of explorative research. A further analysis should validate the feasibility of specific configurations of hub-and-spoke networks in container barge transport empirically. This analysis could be carried out case-wise in which predefined hub-and-spoke network configurations, taking into account their container volumes and waterway characteristics, are tested. Alternatively it could be a more comprehensive analysis in which the hub-and-spoke network configuration that has to be evaluated is the result of a hub network design problem analysis. This approach provides the best configuration that is possible, given the origins and destinations of container flows and the constraints as a result of routing decisions and waterway and vessel size characteristics. For such an analysis an operations research model must be developed. Part of this network analysis should also be the validation of using push boat – push barge formations instead of motor vessels, because such transport units seem to offer more flexible solutions to realise the benefits of these more complex barge network configurations. That is to say, it enables to adapt the vessel size, i.e. the number of push barges in the formation, to the available transport volume and to the waterway dimensions along the route. In view of the important role of the hub on the performance of barge transport services in hub-and-spoke networks a detailed hub terminal design study should also be an element of this research into the feasibility of the hub-and-spoke network.

A second direction of further research concerns the functional and spatial organisation of the terminal landscape. It is still ambiguous whether large terminals are preferable to small terminals and related to that whether the current landscape of terminals is complete or if there is still room for additional terminals. Chapter 8 concluded that the arguments are in favour of a further development of a number of small terminals, as a way to limit pre- and post truck haulage distances and hence the costs of pre- and post truck haulage, which have a rather large share in the total costs of the intermodal barge transport chain. The argument in favour of large terminals, however, is the better opportunity to combine pre- and post truck haulage trips, because of the larger volumes handled by the terminals, but these larger volumes usually also involve larger pre- and post truck haulage distances. It would be interesting to analyse this trade off between these contrary effects of large and small terminals to find the optimal size of a terminal from the perspective of efficient pre- and post truck haulage operations. In addition, the size of a terminal is also ambiguous from the perspective of barge operations that support the competitiveness of intermodal barge transport. On the one hand there is a need for consolidation of flows at inland terminals, particularly in relation to improving the barge handling in ports and hence to improve the quality of hinterland transport. On the other hand, without the existing small terminals the current geographical market coverage of barge transport would be much smaller. Since both large and small terminals have a rationale it seems logical that some kind of hierarchy in inland barge terminals should evolve. How such a terminal landscape should be shaped functionally and geographically remains an interesting topic to further explore, both from a scientific and policy perspective.

A third and important direction of pursuing further research is into the development of an intermodal load unit that would support the development of intermodal barge transport in the continental freight transport market. Standard maritime containers as well as 40’ pallet-wide containers can not compete with the loading capacity of semi-trailers used in road-only transport, which is the norm in the continental freight transport market in which road transport dominates, while existing swap bodies can not be stacked being a precondition for efficient barge transport and are more difficult to handle vertically. From the perspective of loading an intermodal unit optimal with pallets, the 45’ pallet-wide container, which is increasingly used in short sea shipping as a competitive alternative for the semi-trailer in road-only transport, would be an interesting option for intermodal barge transport. However, these containers can not be loaded optimally in the existing fleet of barge vessels, unless they are transported in combination with standard maritime containers. This makes the planning of loading vessels, however, more complex. If the number of 45’ pallet-wide containers is limited, combined transport with standard maritime containers is feasible. However, a large scale implementation of these containers to support continental intermodal barge transport would require alterations in the dimensions of vessels, in particularly the width of vessels. In view of the long life span of vessels such a change in fleet can be a difficult process and can be effective only in the long term. In order to stimulate intermodal transport in Europe the European Commission in 2004 proposed a directive on intermodal load units aiming to make exchanges between modes of transport seamless and to offer a high level of interoperability. However, because of different conflicting interests between the modes of barge, rail and short sea shipping regarding the dimensions and the desired stacking height of such a unit, a promising standard for a European intermodal load unit has not emerged yet. In this research field still valuable work could be done to achieve a breakthrough in a true multimodal intermodal load unit, which supports the development of land-based intermodal transport.

About the author

Rob Konings was born on 12 September 1964 in Roosendaal, the Netherlands. He attended primary school in Fijnaart, and received his VWO diploma from the Norbertus College in Roosendaal in 1982. He commenced his university education in economics at the Erasmus University Rotterdam, where he specialized in spatial and transport economics, and obtained his Master's degree in 1988. His thesis addressed regional economic development in the European Community. Meanwhile, in 1987, he became a research assistant at the Nederlands Economisch Instituut (which merged into Ecorys), and continued in this research post after graduation, until he joined the army for his compulsory military service. During that time he had an administrative position concerned with warehousing and the distribution of furniture for military buildings. In December 1989 he joined the OTB Research Institute for Housing, Urban and Mobility Studies at Delft University of Technology. As a researcher he has worked on a wide variety of research projects, in both contract and fundamental research, which mostly addressed freight transport-related topics, but regularly also passenger transport-related issues. In recent years he has mainly been working in the field of intermodal freight transport. His publications include articles in refereed journals, book chapters, research reports, conference proceedings, and the co-editing of two books on intermodal and automated freight transport.

Samenvatting

Centrale onderzoeksvraag, afbakening en aanpak

In de laatste decennia is het goederenvervoer spectaculair toegenomen. Enerzijds als gevolg van de economische groei, maar anderzijds heeft een groter aanbod van goedkope en hoogfrequente transportdiensten deze economische groei ook mede mogelijk gemaakt. Ondanks de economische bijdrage heeft de toename van het goederenvervoer ook een aantal negatieve effecten teweeg gebracht. De vervoersgroei heeft geleid tot een toenemend aandeel van het vervoer over de weg. Hoewel het belang van het wegvervoer buiten kijf staat, geeft de bijdrage van het goederenwegvervoer aan de verkeerscongestie, emissies en verkeersonveiligheid aanleiding tot zorgen. Gelet op de verwachte groei van het goederenvervoer en de behoefte aan duurzame transportoplossingen is er behoefte aan veranderingen in het transportsysteem. Behalve het wegvervoer duurzamer maken, dienen ook de mogelijkheden te worden benut om alternatieve vervoerswijzen, met name spoorvervoer en binnenvaart, meer te gebruiken. Deze vervoerswijzen beschikken over een grote transportcapaciteit, zijn veiliger en kunnen goede prestaties leveren in termen van zuinig energiegebruik en geringere emissies. Dit proefschrift richt zich op een mogelijk grotere rol die binnenvaart in het vervoer over land zou kunnen spelen.

Van oudsher speelt de binnenvaart een belangrijke rol in het vervoer van bulkgoederen, zowel in het vervoer tussen zeehavens en hun achterland als in het vervoer op andere trajecten die passen bij de karakteristieken van de binnenvaart. De gunstige conditie voor binnenvaart betreft het vervoer van grote hoeveelheden goederen tussen locaties gelegen aan water, waarbij schepen direct aan het water geladen en gelost kunnen worden zonder dat daarbij een relatief dure overslag van en naar de vrachtauto nodig is, zodat kosten van een vrachtautorit vanaf de verlader en naar de ladingontvanger kunnen worden uitgespaard. Onder deze omstandigheden is binnenvaart zeer kosteneffectief, maar gelet op de relatief beperkte dichtheid van het waterwegennet, komen dergelijke gunstige vervoersrelaties niet veel voor.

Het transport van bulkgoederen is bovendien gedurende de laatste decennia geen groeimarkt gebleken en de verwachting is dat deze goederen ook geen grote rol van betekenis zullen spelen in de toekomstige groei van het goederenvervoer. Er vindt een structurele verschuiving in de aard van goederen plaats, waarbij goederen die historisch gezien weinig met binnenvaart in verband gebracht worden de overhand krijgen. Structurele economische veranderingen hebben ertoe geleid dat het vervoersvolume van bewerkte goederen sterker groeit dan dat van grondstoffen, die in bulkvorm worden vervoerd. Daarbij komt dat in veel industriële sectoren, als gevolg van nieuwe logistieke concepten, veranderende klantenwensen en de invloed van Internet, zendingen kleiner en frequenter zijn geworden. Deze ontwikkelingen hebben het wegvervoer in de kaart gespeeld, waardoor het wegvervoer is gegroeid ten koste van de binnenvaart en overigens ook ten koste van het railvervoer.

Om marktaandeel te herwinnen zou binnenvaart een grotere rol moeten spelen in het vervoer van half- en eindproducten en beter moeten inspelen op de behoeften van klanten. De opkomst van de container in het transport van dergelijke producten heeft voor de binnenvaart mogelijkheden gecreëerd om deze producten te gaan vervoeren.

Het gebruik van deze laadeenheden compenseert gedeeltelijk het nadeel van een beperkte dekking van de waterwegen zoals dat de traditionele binnenvaart parten speelt, dat wil zeggen de noodzaak van tijdrovende en dure overslag. Deze laadeenheden maken het bovendien mogelijk om de voordelen van binnenvaart met die van het wegvervoer te combineren, dat wil zeggen de grote flexibiliteit en toegankelijkheid van vrachtauto's om laadeenheden op te halen en weg te brengen. Deze vorm van goederenvervoer, waarbij laadeenheden en een combinatie van vervoerwijzen worden gebruikt, heeft geleid tot een nieuwe, veelbelovende transportmarkt voor de binnenvaart, die bekend staat als intermodale binnenvaart.

Op dit moment vindt binnenvaarttransport met containers plaats, maar met wisselend succes. De containerbinnenvaarttransporten concentreren zich nog steeds op een relatief beperkt aantal routes en in specifieke transportketens: containerbinnenvaart is voornamelijk een *achterlandtransportsysteem* gericht op het landzijdige deel van het *maritieme containerverkeer*. In deze hoedanigheid is de ontwikkeling van intermodale binnenvaart van belang om de bereikbaarheid van het achterland van zeehavens te waarborgen. Echter om een significant marktaandeel in het Europese landtransport te verwerven zouden toepassingen van intermodale binnenvaart verder moeten reiken dan een achterlandtransportsysteem.

Gezien de potentiële bijdrage van binnenvaart aan de verduurzaming van het goederenvervoer, het strategische belang van de binnenvaart voor het transport van containers naar het achterland van zeehavens en de beperkte mogelijkheden tot marktuitbreiding via de traditionele binnenvaart, ligt er een grote uitdaging om de positie van de binnenvaart in de intermodale vervoersmarkt te versterken. Op grond van deze constateringen is de centrale onderzoeksvraag als volgt geformuleerd:

Wat zijn de mogelijkheden en voorwaarden om het marktaandeel van intermodale binnenvaart in Noordwest-Europa te vergroten?

In het beantwoorden van deze vraag is de doelstelling om intermodale binnenvaart als transportsysteem beter te begrijpen, de prestaties van dit systeem te analyseren en aanbevelingen te formuleren voor de binnenvaartsector en beleidsmakers om de concurrentiekracht van intermodale binnenvaart ten opzichte van het unimodale wegvervoer te versterken.

Om het marktaandeel van intermodale binnenvaart te vergroten zijn er in beginsel drie mogelijkheden: (1) het verbeteren van de concurrentiekracht in bestaande markten, dat wil zeggen het verbeteren van de bestaande transportdiensten in het achterlandtransport van containers; (2) het verwerven van een positie van de binnenvaart in nieuwe geografische markten, dat wil zeggen het ontwikkelen van achterlandtransportdiensten naar bestemmingen die tot op heden nog niet bediend werden; (3) het ontwikkelen van intermodale binnenvaart in de markt voor transport van continentale lading.

Om de concurrentiekracht in bestaande markten te verbeteren en nieuwe markten te ontwikkelen dienen de kosten van intermodale binnenvaart te worden gereduceerd en/of moet de kwaliteit van de diensten worden verbeterd. Aangezien intermodale binnenvaart een ketenproces is, bestaande uit binnenvaarttransport, overslag op terminals en voor- en natransport per vrachtauto, moeten deze processen deel uitmaken van de analyse. Het netwerk van binnenvaartdiensten en terminals vormen de kern van een intermodaal binnenvaarttransportsysteem en voor de prestaties van dit systeem, maar voor- en natransport per vrachtauto zal eveneens de concurrentiekracht van het intermodale transportsysteem mede bepalen. De concurrentiekracht wordt bovendien uiteindelijk ook bepaald door de prestaties van concurrerende transportsystemen, de wegvervoersector in het bijzonder.
Deze overwegingen zijn aanleiding geweest om de centrale onderzoeksvraag uit te werken langs drie hoofdthema’s:

1. Netwerkontwerp
2. Knooppunten
3. Concurrentiekracht van ketens

Voor elk van deze thema’s is een onderzoeksvraag opgesteld die door middel van wetenschappelijke artikelen wordt behandeld. Dit proefschrift bestaat zodoende uit een bundeling van wetenschappelijke artikelen.
Hoewel het proefschrift is uitgewerkt langs deze hoofdlijnen streeft het naar een integrale en brede kijk op de prestaties van de keten van intermodale binnenvaart. Het bespreekt de relaties tussen de prestaties op de schakels (onderdelen) van de intermodale binnenvaartketen en hun betekenis voor de concurrentiekracht van intermodale binnenvaart ten opzichte van andere vervoerwijzen. Als zodanig bouwt dit proefschrift voort op onderzoek dat is uitgevoerd in het Europese onderzoeksproject Terminals and Networks (TERMINET), in de periode 1997 tot 2000. Dit onderzoek richtte zich op innovatieve terminals, ten behoeve van het uitwisselen van laadeenheden, en het bundelen van goederenstromen in transportnetwerken.
Vanuit methodologisch oogpunt is dit proefschrift te beschouwen als een systeemanalyse van de intermodale binnenvaart. Het systeem bestaat hierbij uit de elementen die intermodale binnenvaart mogelijk maken, te weten een infrastructuurnetwerk dat bestaat uit verbindingen en knooppunten, en transporteenheden (schepen en vrachtauto’s) voor het vervoer van containers over de verbindingen door knooppunten (terminals) vanaf verladers naar ladingontvangers. Het beslaat de drie ketenactiviteiten binnenvaarttransport, overslag en vrachtautotransport vanuit een *economisch perspectief* en beschouwt het belang van deze activiteiten met het oog op een mogelijke verbetering van de prestaties van het intermodale

binnenvaarttransportsysteem en hun betekenis voor de concurrentiekracht ten opzichte van andere vervoerwijzen.
Geografisch gezien richt het proefschrift zich op de ontwikkeling van intermodale binnenvaart in Noordwest-Europa.

Samenvatting van de resultaten en conclusies

In de uitwerking van de centrale onderzoeksvraag zijn drie hoofdthema's geformuleerd die zijn onderzocht: netwerkontwerp, knooppunten en ketenconcurrentiekracht. Deze paragraaf beschrijft de onderzoeksvragen die voor elk van deze thema's zijn geformuleerd, vat de belangrijkste bevindingen per onderzoeksvraag samen en geeft de belangrijkste conclusies.

Netwerkontwerp

Onderzoeksvraag 1: *Wat zijn de bepalende factoren voor de prestaties van intermodale binnenvaartdienstennetwerken en welke typen diensten zijn het meest belovend om het marktaandeel van intermodale binnenvaart te vergroten?*

Deze vraag gaat over de factoren die de kosten en kwaliteit van transportdiensten in de containerbinnenvaart bepalen. De hypothese is dat de kosten en kwaliteit van deze transportdiensten sterk verband houden met het type netwerk waarbinnen zij worden uitgevoerd. Een netwerk wordt hierbij opgevat als een dienstennetwerk, dat beschouwd kan worden als het productiemodel van transportdiensten. Dit geeft weer hoe transportdiensten worden gepland, uitgevoerd en langs welke route. Netwerkontwerp omvat hier zodoende het vinden van dienstennetwerken die de beste prestaties leveren. De hoofdstukken 2, 3 en 4 gaan in op deze onderzoeksvraag.
Er is een conceptueel model voor het ontwerp van binnenvaartnetwerken ontwikkeld. Dit model beschrijft de ontwerpvariabelen voor binnenvaartnetwerken en toont de relaties tussen prestatie-indicatoren voor intermodale binnenvaart vanuit het perspectief van de binnenvaart operator en de ladingbelanghebbenden (verzenders en ontvangers van goederen). Het model laat zien dat de scheepsgrootte (schaalomvang) en de omlooptijd van een schip primaire invloedsfactoren zijn op de kosten en kwaliteit (dat wil zeggen de frequentie, doorlooptijd en betrouwbaarheid) van de binnenvaarttransportdiensten. Het zijn beslissingsvariabelen die samenhangen met het dienstennetwerkontwerp.
De scheepsgrootte heeft vanzelfsprekend een directe invloed op de kostenprestatie, maar het beschikbare vervoersvolume (de vraag naar transport) speelt een belangrijke rol in de keuze van de scheepsgrootte. Gegeven een beschikbaar vervoersvolume speelt de scheepsgrootte ook een rol met betrekking tot de frequentie van de transportdiensten. Theoretisch is een uitruil denkbaar tussen de grootte van het in te zetten schip en de frequentie van diensten, maar er kan niet voorbij worden gegaan aan de wensen van de klanten. Klanten verlangen voldoende afvaarten per week en dus is een zekere minimale dienstenfrequentie vereist. Hoe korter de afstand hoe hoger doorgaans de vereiste frequentie. Als het beschikbare vervoersvolume toeneemt, wordt het extra vervoersaanbod meestal eerst gebruikt om het aantal afvaarten te vergroten en vervolgens wordt dan eventueel een groter schip ingelegd. Daarnaast zal de keuze van de grootte van het in te leggen schip niet alleen bepaald worden

door economisch operationele overwegingen, maar ook door eventuele beperkingen die voortvloeien uit de karakteristieken van de waterwegen.

De omlooptijd, gedefinieerd als de tijd tussen vertrek van een binnenvaartschip bij een terminal en het volgende vertrek van hetzelfde binnenvaartschip vanaf die terminal, is de andere belangrijke bepalende factor voor de kosten en kwaliteit van de binnenvaarttransportdiensten. De omlooptijd van schepen is een indicator voor hun benuttingsgraad. Indien meer rondreizen gemaakt kunnen worden in hetzelfde tijdsbestek, worden de vaste kosten uitgesmeerd over meer transportdiensten, en daarmee dalen de kosten per laadeenheid. Aangezien de vaste kosten een groot aandeel hebben in de kosten van binnenvaarttransport, is dit een belangrijk aanknopingspunt om kosten te verlagen. Anderzijds houdt de omlooptijd ook verband met de transporttijd van diensten. Als de omlooptijd korter is, kan de transporttijd van een dienst ook korter worden, wat een kwaliteitsverbetering oplevert voor de ladingbelanghebbenden.

De relatie tussen de omlooptijd en het vaarschema van binnenvaartschepen speelt een rol ten aanzien van de betrouwbaarheid van de transportdiensten. Er is doorgaans een voorkeur voor omlooptijden die een veelvoud zijn van 24 uur om regelmatige vaarschema's aan te houden, dat wil zeggen dezelfde (dagelijkse) vertrektijd voor een bepaalde dienst. In de omlooptijden is meestal enige speling aanwezig om eventuele vertragingen te kunnen opvangen en desondanks dit 24-uurspatroon te kunnen aanhouden. In welke mate binnen een vaarschema speling aanwezig is in de omlooptijd is een bepalende factor voor de betrouwbaarheid van de transportdiensten.

De omlooptijd van een schip wordt bepaald door (1) de vaartijd, die bepaald wordt door de transportafstand en de vaarsnelheid, die mede afhankelijk is van de karakteristieken van de waterwegen, (2) andere kenmerken van de waterwegen, zoals de aanwezigheid van sluizen en bruggen. Als bruggen geopend moeten worden om ze te kunnen passeren kan dit wachttijd opleveren, (3) de verblijftijd op terminals, die bestaat uit behandel- en wachttijd. Hierbij speelt het aantal terminals dat bezocht moet worden ook een rol. De keuzes betreffende het aantal en de locatie van terminals die met een binnenvaarttransportdienst worden bezocht, alsook de keuzes over de wijze waarop verschillende binnenvaarttransportdiensten aan elkaar worden gekoppeld vormen de basis van het netwerkontwerp. Bijvoorbeeld de keuze om een punt-puntdienst te ontwikkelen in plaats van een lijndienst, heeft directe invloed op de omlooptijd, maar houdt ook verband met de keuze van de scheepsgrootte.

Met andere woorden, de scheepsgrootte en de omlooptijd van een schip zijn geen onafhankelijke beslissingsvariabelen, maar hangen met elkaar samen. Een groter schip heeft een langere laad- en lostijd. De omlooptijd neemt daardoor toe, zeker indien meerdere terminals bezocht moeten worden waardoor mogelijk geen efficiënt vaarschema meer kan worden aangehouden. De consequentie is dat het aantal rondreizen dat kan worden gemaakt afneemt. Dit heeft een negatief effect op de transportenkosten per laadeenheid.

De relaties tussen de variabelen in dit conceptuele model ogen simpel, maar er zijn verschillende afhankelijkheden die dit raamwerk complex maken. In de eerste plaats blijkt een uitruil mogelijk tussen de kosten en kwaliteit van de binnenvaarttransportdiensten, die het resultaat zijn van de relatie tussen de omvang en de omlooptijd van schepen. In de tweede plaats zijn de beslissingen over scheepsomvang en omlooptijd het resultaat van het ontwerp van het dienstennetwerk. Deze beslissingen worden echter ook beïnvloed door het vervoersvolume en de transportafstand en door de dimensionering van de waterwegen en de eventuele aanwezigheid van sluizen en bruggen. De hoofdconclusie is dat de keuze voor een bepaald dienstennetwerk bepaald wordt door de kenmerken van de transportmarkt en de waterwegeninfrastructuur.

Deze bevindingen ondersteunen de hypothese dat de kosten en kwaliteit van binnenvaarttransportdiensten afhangen van de netwerken waarin ze plaatsvinden, maar bevestigen ook dat het type binnenvaarttransportdienst dat het beste kan worden ingevoerd om marktaandeel te verwerven, afhankelijk is van de kenmerken van de transportmarkt en de waterwegeninfrastructuur. Markten met sterk geconcentreerde grote goederenstromen vragen dan ook een ander type netwerk dan markten met kleine verspreide goederenstromen. Daarnaast kan de kwaliteit van de waterwegen een beslissingsvariabele zijn voor de route van schepen in het netwerk, maar vanzelfsprekend ook voor de keuze van de scheepsgrootte.

In hoofdstuk 2 is dit conceptuele model empirisch toegepast in een case-studie naar het achterlandtransport tussen de zeehaven Rotterdam en Duisburg in Duitsland. Hierin werd aangetoond dat er verbeteringen in de prestaties van binnenvaartdiensten mogelijk zijn door het lijndienstennetwerk te veranderen in een netwerk met punt-puntdiensten.

In hoofdstuk 3 is de specifieke rol van de karakteristieken van de waterwegeninfrastructuur voor het netwerkontwerp uitgewerkt en empirisch getoetst. Om containerbinnenvaarttransport op kleinere waterwegen verder te ontwikkelen, zijn in dit hoofdstuk de mogelijkheden van het ‘trunkline-feeder’ (stamlijn-aan/afvoerlijn)-netwerk beschouwd. Daarmee zouden de prestaties van bestaande diensten op kleine vaarwegen kunnen verbeteren of nieuwe geografische markten voor containerbinnenvaart kunnen worden ontsloten. De gedachte van dit netwerk is dat, in plaats van een directe dienst naar bestemmingen langs een kleine waterweg, de dienst wordt opgesplitst in een aan/afvoerdienst op de kleine vaarweg die aansluit op een stamlijndienst die aangeboden wordt op een grote(re) vaarweg. Uit de analyse bleek dat het vervangen van een directe binnenvaartdienst door een ‘trunk-feeder’-dienst de kosten en kwaliteit van binnenvaartdiensten naar bestemmingen langs kleine waterwegen kan verbeteren. Er zijn echter verschillende factoren die de prestaties van dit type netwerk beïnvloeden. De configuratie van het netwerk (de lengte van de aan/afvoerverbinding in relatie tot de lengte van de stamlijnverbinding) is belangrijk. Daarnaast zijn het beschikbare transportvolume, diverse extern bepaalde omstandigheden (zoals vaarsnelheidvoorschriften, sluizen, doorvaarhoogtes en prestaties van terminals) en operationele beslissingen (zoals het type schip, de frequentie van diensten en mogelijkheden tot boord-boordoverslag) van belang. De beoordeling van de commerciële haalbaarheid van een dergelijke trunk-feeder dienst zal daarom van geval tot geval moeten plaatsvinden. De implementatie van deze diensten is dan ook een kwestie van maatwerk.

Hoofdstuk 4 richtte zich op een ander type netwerk als alternatief voor de tot op heden gebruikelijke lijndiensten- en punt-puntdienstennetwerken. Het hoofdstuk verkent de wenselijkheden en mogelijkheden van ‘hub-and-spoke’ netwerken in de containerbinnenvaart. Het vertrekpunt voor deze verkenning was een algemene beschouwing over de kenmerken van hub-and-spoke netwerken in transport. Geconcludeerd werd dat de typische kenmerken van hub-and-spoke netwerken zeer ondersteunend zouden kunnen zijn voor een uitbreiding van de markt voor containerbinnenvaart. In de eerste plaats zorgen de operationele kenmerken van dit netwerk ervoor dat het hub-and-spoke netwerk erg geschikt is om nieuwe diensten te ontwikkelen tussen herkomsten en bestemmingen waarvoor het vervoersvolume nog te klein is om een directe (punt-punt)binnenvaartdienst te ontwikkelen. In de tweede plaats biedt de stervormige structuur van dit netwerk bij uitstek kansen om de geografische dekking van binnenvaarttransportdiensten te verruimen.

De belangrijkste voorwaarden voor de levensvatbaarheid van hub-and-spoke binnenvaartnetwerken zijn lange verbindingen (spokes) en een efficiënte, betrouwbare en snelle uitwisseling van containers in de centrale overslaghaven (de hub) om de kosten en tijd van additionele overslag te beperken. De kosten van additionele overslag kunnen worden gecompenseerd door lagere kosten op de verbindingen van het netwerk. Deze compensatie is gemakkelijker te realiseren op langere vaarafstanden. Het beperken van tijdsverlies vergt een snel overslagproces in de hub, maar ook onderlinge afstemming van de vaarschema's van de schepen op de verbindingen. Dit nadeel van tijdsverlies kan overigens beperkt blijven, omdat het afhangt van het relatieve tijdsverlies op de totale transporttijd van de containers, alsook van de tijdgevoeligheid van de vervoerde goederen.

Samenvattend, het antwoord op de vraag welke netwerken voor binnenvaartdiensten het meest belovend zijn om het marktaandeel van de binnenvaart te vergroten is afhankelijk van de karakteristieken van de transportmarkt en de waterwegeninfrastructuur. Het meest wenselijke netwerk moet beoordeeld worden in het licht van de specifieke transportmarkt en de infrastructurele omstandigheden. Markten met sterk geconcentreerde grote goederenstromen vereisen een ander type netwerk dan markten met kleine verspreide goederenstromen. Daarnaast kan de kwaliteit van de vaarwegen een beslissingsvariabele zijn voor de route van schepen in het netwerk, maar vanzelfsprekend ook voor de keuze van de scheepsgrootte.

Indien het vervoersvolume tussen een herkomst en bestemming groot genoeg is om directe, frequente diensten aan te bieden, is het punt-puntdienstennetwerk de ideale netwerkconfiguratie. Aangezien het een directe dienst zonder tussenstops is, kan het de beste prestaties bieden: een korte transporttijd, een hoge betrouwbaarheid en lage kosten vanwege het ontbreken van tussentijdse overslag. Indien het vervoersvolume te klein is voor punt-puntdiensten, kunnen lijndiensten een alternatief zijn, maar die hebben dan wel het nadeel van een langere transporttijd en mogelijk minder hoge betrouwbaarheid, omdat meerdere terminals worden bezocht. Hoewel elke container slechts één keer wordt geladen en gelost, zijn de vaarkosten in dit type diensten in principe hoger vanwege een grotere omlooptijd van het schip. Daarnaast kunnen ook complexere netwerken worden overwogen, waarin intermediaire overslag nodig is, zoals in het trunk-feeder netwerk en het hub-and-spoke netwerk.

Het feit dat deze complexere netwerken bestaan uit diensten met tussentijdse overslag heeft een groot voordeel. Het biedt de mogelijkheid om punt-puntdiensten tussen de terminals in het hub-and-spoke netwerk en in het feedergedeelte en mogelijk ook in het stamlijngedeelte van het trunk-feeder netwerk in te leggen, waardoor de omlooptijd van schepen beperkt kan blijven en een schip productiever kan zijn. Bovendien kan dan de scheepsgrootte volledig worden afgestemd op de dimensies van vaarwegen op de spoke-, stamlijn- en feederverbindingen, waardoor schaalvoordelen benut worden.

Het belangrijkste nadeel is echter de noodzaak van tussentijdse overslag, dat tijd en geld kost, met als gevolg een langere transporttijd en mogelijke aantasting van de betrouwbaarheid van de diensten. De additionele overslagkosten kunnen echter worden gecompenseerd door lagere kosten op de verbindingen in het netwerk. Dit vereist wel dat de lengte van de routes lang genoeg zijn.

Over het algemeen lijken de trunk-feeder diensten het meest belovende type netwerk om de het geografisch bereik van containerachterlandtransport te vergroten, terwijl hub-and-spoke netwerken bij uitstek geschikt lijken om nieuwe markten aan te boren, in het bijzonder de markt voor continentale lading.

De operationele eisen in hub-and-spoke netwerken duiden erop dat een dergelijk netwerk alleen op grote geografische schaal kan worden ontwikkeld, in dit geval op internationale Europese schaal. Bovendien zijn er gelet op de ligging en kwaliteit van de vaarwegen in Noordwest-Europa niet veel plaatsen waar deze netwerken ontwikkeld zouden kunnen worden.

De meest belovende strategie om hub-and-spoke netwerken te ontwikkelen is door reeds goed ontwikkelde achterlanddiensten deel te laten uitmaken van dit netwerk. Dit biedt basislading om nieuwe spokeverbindingen te ontwikkelen waarin maritieme en continentale lading kan worden gebundeld. De bundeling van deze ladingstromen, die goedkopere en frequente diensten mogelijk maakt, kan uitgroeien tot een zichzelf versterkend proces.

Knooppunten

Onderzoeksvraag 2: *Wat is de rol van terminals in de kosten- en kwaliteitsprestatie van intermodale binnenvaart en hoe kunnen terminals bijdragen aan een betere prestatie?*

Deze onderzoeksvraag richt zich enerzijds op het vraagstuk van de overslagkosten die inherent zijn aan intermodaal vervoer en de mogelijkheden deze kosten te beperken, en anderzijds op de mogelijkheden van kwaliteitsverbetering door het ontwikkelen van additionele functies van terminals. De uitwerking van deze vraag kan worden toegepast op een individuele terminal, maar ook kan een bredere ruimtelijke invalshoek worden gekozen. In dat laatste geval is het beter om te spreken over knooppunten.

Allereerst is een analyse uitgevoerd naar de mogelijkheden om de afhandeling van containerbinnenvaartschepen in de haven van Rotterdam te verbeteren (hoofdstuk 5). De essentie van dit probleem is dat de afhandeling te traag verloopt omdat de schepen teveel terminals in de zeehaven moeten aandoen. Dit kost veel tijd en gaat gepaard met congestie en wachttijden bij terminals, omdat veel binnenvaartschepen dezelfde terminals bezoeken en de capaciteit van de terminals gedeeld wordt met zeeschepen die prioriteit krijgen in de afhandeling. Daardoor lopen de binnenvaartschepen vertragingen op. Als gevolg hiervan moeten barge operators ruime marges in hun vaarschema opnemen om de betrouwbaarheid van de diensten te kunnen waarborgen. De schepen verblijven relatief lang in de zeehaven en dit heeft een negatieve invloed op de transporttijd van containers en de kosten van de binnenvaartdiensten zijn daardoor hoog. Deze slechte kwaliteit in de afhandeling van binnenvaartschepen in de haven werkt uiteindelijk dus negatief uit op de concurrentiekracht van de containerbinnenvaartdiensten.

Uit deze beschrijving blijkt dat het probleem is te karakteriseren als een knooppuntprobleem dat zich voordoet op het niveau van de gehele haven. Als mogelijke oplossingsrichting is in dit hoofdstuk daarom een reorganisatie van de binnenvaartdiensten voorgesteld en uitgewerkt. Het idee is dat de bestaande diensten worden gesplitst in een stamlijndienst tussen haven en achterland en collectie/distributiediensten binnen de haven.

Drie configuraties van dit type dienstennetwerk zijn op hun economische haalbaarheid getoetst. Uit deze analyse werd geconcludeerd dat deze diensten de concurrentiekracht van het containertransport naar het achterland kunnen verbeteren, maar de resultaten hangen af van het specifieke ontwerp en de organisatie van het collectie/distributietransport en de vaarafstanden en tarieven van de stamlijndiensten.

Hoofdstuk 6 richt zich op de terminalprocessen en de prestaties van terminals. Het bespreekt toekomstige eisen aan binnenvaartterminals en de mogelijkheden om hun prestaties te verbeteren, zodat zij kunnen bijdragen aan een grotere concurrentiekracht van intermodale binnenvaart. Er wordt betoogd dat nieuwe terminal- en overslagconcepten containerbinnenvaarttransport attractiever kunnen maken. Enkele concrete ontwerpen worden besproken om dit te illustreren.

Hoofdstuk 7 is gewijd aan een concept waarin een ruimtelijke en functionele integratie van containeroverslag met opslag, collectie en distributie van goederen hoogwaardige intermodale transportoplossingen mogelijk maakt. Er wordt gesteld dat de rol van een terminal verder moeten reiken dan uitsluitend overslagvoorziening tussen verschillende vervoerwijzen. Een belangrijk onderdeel van dit concept is een intern transportsysteem dat niet alleen gebruikt wordt voor terminalprocessen, waaronder het transport naar containeropslagplaatsen, maar ook voor het transport tussen terminal en containerladingverzendende en -ontvangende bedrijven die op een terrein nabij de terminal zijn gevestigd. Met het interne transportsysteem wordt de functionele integratie van deze activiteiten bewerkstelligd. De ruimtelijke integratie van containeroverslag, -opslag en -ladingbehandeling is eveneens een belangrijk element, omdat de onderlinge nabijheid van deze activiteiten bijdraagt aan een efficiëntere organisatie van het voor- en natransport in de intermodale keten, zoals dat verder is uitgewerkt in onderzoeksvraag 3. Dit concept van geïntegreerde overslagcentra toont aan dat innovatieve terminalconcepten intermodaal vervoer aantrekkelijker kunnen maken.

Een eerste algemene conclusie is dat terminals een belangrijke rol spelen in de kwaliteits- en kostenprestaties van intermodale binnenvaart. Terminaloverslagkosten hebben een significant aandeel in de totale kosten van de intermodale binnenvaartketen. Dit geldt voor de overslag op inland terminals, maar nog meer voor de binnenvaartoverslag in zeehavens.

Een tweede conclusie is dat de rol van terminals deel moet uitmaken van analyses van netwerken van binnenvaartdiensten. Kenmerken en functies van binnenvaartterminals kunnen een voorwaarde zijn om nieuwe binnenvaartdienstennetwerken te kunnen ontwikkelen, om daarmee de positie van de binnenvaart in de huidige markt voor containerachterlandvervoer te versterken of nieuwe achterlandtransportmarkten en de continentale ladingmarkt te kunnen aanboren. Anderzijds kunnen de prestaties van terminals op hun beurt ook worden beïnvloed door de kenmerken van binnenvaartdienstennetwerken. De analyse van de afhandeling van binnenvaartschepen in de haven van Rotterdam (hoofdstuk 5) liet zien dat door het dienstennetwerk naar het achterland te herzien een verbetering in de afhandeling in de zeehaven mogelijk is. Er is aldus een wederzijdse relatie tussen de prestaties van dienstennetwerken en terminals.

Wat betreft de mogelijke bijdrage van terminals aan betere prestaties van intermodale binnenvaart blijkt een gedifferentieerde aanpak gewenst in het ontwikkelen van nieuwe terminal- en overslagconcepten. De belangrijkste drijfveren voor deze gedifferentieerde aanpak zijn de containervolumes en de positie van de terminal in het netwerk. Feitelijk zijn er drie ‘locaties’ in het netwerk waar binnenvaartoverslaginnovaties op maat gewenst zijn: (1) in de zeehaven, (2) in de haarvaten van het vaarwegennet en (3) in meer complexe dienstennetwerken, onder meer ter ondersteuning van hub-and-spoke netwerken.

Concurrentiekracht van ketens
Onderzoeksvraag 3: *Wat zijn de kansen om de concurrentiekracht van de intermodale binnenvaartketen te versterken en wat zijn de bedreigingen?*

In de uitwerking van deze onderzoeksvraag wordt de mogelijke bijdrage van netwerken van binnenvaartdiensten en terminals aan de concurrentiekracht van intermodale binnenvaart in breder perspectief geplaatst. Uiteindelijk speelt de prestatie van de totale transportketen een doorslaggevende rol in de concurrentiestrijd met het wegvervoer. Dit aspect is uitgewerkt in hoofdstuk 8 en 9.

In hoofdstuk 8 is onderzocht op welk geografisch schaalniveau intermodale transportdiensten concurrerend kunnen zijn met wegvervoer. Het bespreekt het marktbereik van intermodaal vervoer. Dit raakt aan het vraagstuk van de dichtheid van intermodale netwerken, de schaal van intermodale terminals en de omvang van het bedieningsgebied van een terminal met voor- en natransport per vrachtauto. Aangezien dit voor- en natransport doorgaans onvermijdelijk is vanwege het beperkte bestrijkingsgebied van de waterwegen, is het belangrijk om inzicht te hebben hoe deze ritten de prestaties van de intermodale binnenvaartketen beïnvloeden. In de bespreking van de relaties tussen netwerk- en terminalprocessen en deze ritprocessen komt aan de orde in welke mate er synergie is of afwegingen mogelijk zijn tussen de prestaties van deze ketenactiviteiten. De conclusie van deze bespreking is dat er geen blauwdruk bestaat van het schaalniveau waarop intermodaal vervoer concurrerend is met wegvervoer. De kenmerken van het ‘transportlandschap’, voornamelijk getypeerd door de vervoersvolumes en de herkomsten en bestemmingen van lading, bepalen of aantrekkelijke intermodale binnenvaartdiensten kunnen worden aangeboden. De uitdaging is om voor het transportlandschap een passend dienstennetwerk te vinden. Verder wordt de belangrijke rol van het voor- en natransport per vrachtauto voor de totale kostenprestatie van intermodale binnenvaart bevestigd. Belangrijke kostenbesparingen in dit voor- en natransport kunnen worden gerealiseerd door een verbeterde organisatie van deze ritten (d.w.z. het combineren van beladen ritten), maar de mogelijkheden hiervoor blijken mede afhankelijk van de kenmerken van het transportlandschap: het transportvolume, de onbalans van inkomende en uitgaande ladingstromen door de terminal, alsook de locatie van klanten ten opzichte van de terminal en ten opzichte van elkaar. Grotere vervoersvolumes kunnen leiden tot lagere overslagtarieven; dat maakt het mogelijk om bij gelijkblijvende totale intermodale ketenkosten over grotere afstanden voor- en natransport te verrichten. Als gevolg hiervan wordt het bedieningsgebied van de terminal verruimd, waardoor meer ritten kunnen worden gecombineerd. Op deze manier is er een wederzijdse relatie tussen de kostenprestatie van terminals en het voor- en natransport.

Veel van de algemene noties over de prestaties van transportketens die in hoofdstuk 8 zijn besproken, zijn verder uitgewerkt en toegepast in een bijzonder transportconcept voor intermodale binnenvaart, namelijk een zee-rivierduwbaksysteem. De concurrentiekracht van dit systeem ten opzichte van andere vervoerswijzen, waaronder wegvervoer, werd onderzocht voor beoogde diensten met dit systeem op de corridor tussen Groot-Brittannië en Duitsland. Hiervoor werd een model ontwikkeld waarmee de beste keuze van aanloophavens in deze dienst kon worden bepaald. Het model beschouwt de kwaliteiten van transportdiensten en de potentieel beschikbare vervoervolumes in samenhang om daaruit de meest aantrekkelijke diensten voor dit zee-riviervaartsysteem af te leiden. De conclusie was dat zo’n dienst het beste wordt ontwikkeld over relatief korte afstanden, omdat zodoende de tijdsbesparing door

het vermijden van een overslag in de zeehaven relatief gezien het grootst is. Deze conclusie bevestigt dat een korte omlooptijd van schepen van groot belang is voor de prestaties van de intermodale binnenvaart, zowel wat betreft kosten als wat betreft transporttijd.
De concurrentiekracht van het intermodale transportsysteem wordt niet alleen bepaald door de eigen prestaties, maar ook door die van concurrerende vervoerwijzen. Andere modaliteiten, zoals het wegvervoer, proberen ook voortdurende hun prestaties te verbeteren om hun marktpositie te versterken. Vanuit dit perspectief is in hoofdstuk 10 de tariefstelling van het containerwegvervoer onderzocht, dat, hoewel het voor de intermodale binnenvaart een externe factor is, een belangrijk thema is voor de concurrentiekracht van intermodale binnenvaart. Uit deze analyse bleek dat de marktstructuur van het containerwegvervoer overeenkomt met het theoretische model van volledige mededinging. Volgens dit model hebben de wegvervoerders grote moeite om winstgevend te opereren en door hevige concurrentie in de markt tendeert het transporttarief naar kostprijsniveau of zelfs daaronder. Hoewel de wegvervoersector de afgelopen tien jaar is geconfronteerd met forse kostenstijgingen, met name voor brandstof en tol (zoals de Maut in Duitsland) heeft de sector deze kosten kennelijk door productiviteitsverbetering kunnen opvangen, waardoor de tarieven op een relatief laag niveau zijn gebleven en daarmee wegvervoer concurrerend is gebleven. Het succes van het wegvervoer is daarnaast ook te danken aan haar grote flexibiliteit, in termen van bereikbaarheid en mogelijkheden om direct te kunnen inspelen op veranderende wensen van klanten, hetgeen deze sector minder kwetsbaar maakt voor veranderende marktomstandigheden dan de binnenvaartsector. Daarnaast kan onzekerheid over de bevaarbaarheid van waterwegen door hoog of laag water of ijsvorming de binnenvaart parten spelen, wat maakt dat het belangrijk is dat alternatieve vervoersmogelijkheden (weg- of spoorvervoer) kunnen worden aangeboden. Deze vorm van flexibiliteit is belangrijk om de betrouwbaarheid van binnenvaart te kunnen waarborgen.

De belangrijkste conclusie die uit dit deel van het proefschrift kan worden getrokken is dat de ketenbenadering cruciaal is voor de prestaties van intermodale binnenvaart en haar concurrentiepositie ten opzichte van andere modaliteiten. Er kan synergie optreden tussen de verschillende schakels in de intermodale binnenvaartketen. Deze mogelijkheden hebben niet alleen betrekking op organisatorische verbeteringen in de keten, maar ook de ruimtelijke dimensie speelt een rol, dat wil zeggen met ruimtelijke ordening kan een belangrijke bijdrage aan de concurrentiekracht van intermodale binnenvaart worden geleverd. Het succes van versterking van de concurrentiekracht van intermodale binnenvaart hangt, zoals eerder aangegeven, ook af van de ontwikkeling van de prestaties van het wegvervoer, dat in toenemende mate geconfronteerd wordt met beperkingen bij het verbeteren van haar prestaties. Echter, aangezien voor- en natransport per vrachtauto een bijna onvermijdelijk onderdeel is van intermodale binnenvaart, kan een verslechtering van de prestaties van het wegvervoer ook de relatieve prestaties van intermodale binnenvaart beïnvloeden.

Implicaties voor beleid

In dit proefschrift zijn een aantal ontwikkelingsstrategieën voorgesteld om de kosten en kwaliteitsprestatie van intermodale binnenvaart te verbeteren teneinde met binnenvaart een groter marktaandeel te verwerven. Het transportbeleid speelt een niet onbelangrijke rol in het verwezenlijken van deze strategieën. Vier beleidsvraagstukken vragen hier om bijzondere aandacht.

In de eerste plaats ligt er een belangrijke beleidsopgave de kwaliteit van de vaarwegen op te waarderen, waaronder een verbetering van de connectiviteit en interoperabiliteit in het waterwegennet. Om nieuwe intermodale binnenvaartdiensten te kunnen ontwikkelen en nieuwe markten te kunnen ontsluiten is een geïntegreerd waterwegennet op Europese schaal nodig. In de huidige samenhang van waterwegen lijkt eerder sprake van het bestaan van vier grote corridors[34] dan van een netwerk. Om een Europees netwerk tot stand te brengen moeten enkele ontbrekende schakels tussen deze corridors worden aangelegd, te weten een verbinding tussen de Rhone-Saone en Moezel, tussen de Elbe-Oder en de Donau en tussen Twentekanaal en het Mittellandkanaal. Dergelijke strategische investeringen staan nog niet geprogrammeerd op de Europese politieke agenda. Het huidige Europese beleid voor de waterwegeninfrastructuur, dat wordt uitgevoerd in het kader van het programma Trans-Europese transport netwerken (TEN-T), is gericht op verbetering van schakels binnen de bestaande corridors, zoals de aanleg van het Seine-Nordkanaal en het oplossen van knelpunten op de grote binnenvaarttransportas Rijn-Main-Donau.

Andere gewenste maatregelen om de kwaliteit van de vaarwegen te verbeteren betreffen verbreding van waterwegen en vergroting of ten minste behoud van de diepgang, zij het dat het voor de containerbinnenvaart van groter belang is dat renovatie van sluizen en bruggen plaatsvindt en de openingstijden van sluizen en bruggen worden gecoördineerd. Vanzelfsprekend zijn deze maatregelen het meest effectief als ze een hele corridor betreffen. Dergelijke infrastructurele verbeteringen worden uitgevoerd door nationale, regionale en lokale overheidsinstanties, maar in een relatief laag tempo. De Nederlandse consultant NEA[35] constateerde dat in de periode van 1995 tot 2005 slechts 4% van de investeringen in transportinfrastructuur is besteed ten behoeve van vervoer over water, waarvan 3% in havens en 1% in de waterwegen, terwijl het vervoersvolume op de waterwegen met meer dan 10% groeide. Daarentegen ging 63% van het totale investeringsbudget naar wegen en 33% naar spoorwegen. Het uitgangspunt is dat onderhoud van infrastructuur prioriteit krijgt boven uitbreiding, maar door beperkte budgetten is er sprake van achterstallig onderhoud, waaronder voor sluizen en bruggen. Aangezien de onderhoudsuitgaven vooral ten behoeve van grote vaarwegen worden gepleegd, blijft er wat de betreft de staat van de kleine vaarwegen nog veel te wensen over. Om het geografische marktbereik van intermodale binnenvaart te behouden of te kunnen vergroten, moeten deze achterstanden in het onderhoud worden weggewerkt.

In de tweede plaats is het belangrijk, mede gezien het belang van de kleine vaarwegen voor de verdere ontwikkeling van intermodale binnenvaart, dat kleine schepen deel blijven uitmaken van de binnenvaartvloot, wat veronderstelt dat er in de exploitatie van deze schepen een toekomstperspectief is. De dringende behoefte aan ondersteunend beleid op dit punt is door de belangrijkste brancheorganisaties van de binnenvaart in Nederland door middel van een actieplan eind 2008 onder de aandacht gebracht bij de Nederlandse nationale overheid. Dit plan bevat zeer uiteenlopende actiepunten, waaronder aangepaste bemanningsvoorschriften,

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[34] *Rijncorridor*: het stroomgebied van de Rijn en haar zijrivieren, waarmee delen van Nederland, het westen van Duitsland, België, Luxemburg, Frankrijk en Zwitserland worden ontsloten; *Oost-West corridor*: beslaat delen van Noord-Duitsland, Polen en Tsjechië; *Donau-corridor*: het stroomgebied van de Donau, waarmee Zuidoost-Duitsland, Oostenrijk, Slowakije, Hongarije, Roemenië en Bulgarije worden ontsloten; *Noord-Zuid-corridor*: verbindt delen van Nederland, België en Frankrijk.

[35] NEA, 2009, Do modes get what they deserve?, Rijswijk.

fiscale en sociale regelgeving, het stimuleren van nieuwbouw van kleine schepen en imagoverbetering.

In de derde plaats is er een rol weggelegd voor beleid ten aanzien van de functie en positie van knooppunten in het intermodale binnenvaarttransportsysteem. Overheden kunnen een voorwaardescheppende rol spelen voor de ontwikkeling van binnenhavens en multimodale overslagvoorzieningen. In dit verband is er behoefte aan ruimtelijk ordeningsbeleid dat de ontwikkeling van bedrijventerreinen aan vaarwater ondersteunt. Dit maakt belangrijke besparingen in de kosten van voor- en natransport mogelijk, maar creëert ook gunstige condities voor het ontwikkelen van overslagfaciliteiten om de bedrijven die op die bedrijventerreinen zijn gevestigd, te bedienen.

In de vierde plaats speelt het vraagstuk van de internalisering van de externe kosten van het transport. Dit is al jaren een onderwerp van politieke discussie, maar internalisering zal vroeg of laat toch gaan plaatsvinden. Deze doorberekening van de externe kosten zal de concurrentieverhoudingen tussen binnenvaart en de andere modaliteiten, waaronder wegvervoer, beïnvloeden. Een belangrijke stap in deze richting is gezet met een voorstel voor doorberekening van externe kosten waaraan het Europese Parlement haar goedkeuring heeft gegeven. Dit voorstel richt zich in eerste instantie op doorberekening van de externe kosten van het wegvervoer, waarbij emissies en geluidsproductie, naar de wegvervoerbedrijven worden doorberekend, en uiteindelijk mogelijk ook de congestiekosten. Dit zal het wegvervoer zonder twijfel duurder maken. De plannen voor de doorberekening van externe kosten naar de andere modaliteiten zijn nog minder ver uitgewerkt. Tot dusverre lijkt binnenvaart slechts alleen verplicht tot het overstappen naar een duurdere, milieuvriendelijke brandstof. Hoe dit politieke proces van internalisering van externe kosten uiteindelijk de concurrentiekracht van de binnenvaart beïnvloedt, valt te bezien. Behalve op grond van zuiver politieke motieven zal het resultaat ook afhangen van de mate waarin de binnenvaartsector zichzelf ontwikkelt tot een meer milieuvriendelijke vervoerswijze. Dit is echter geen vanzelfsprekend proces, maar dit wordt grotendeels gestuurd door van overheidswege opgelegde normen. Als gevolg van de lange levensduur van schepen kan de binnenvaart minder snel nieuwe milieusparende technologie in de vloot invoeren, in tegenstelling tot de wegvervoersector. Bovendien, door de onzekerheid over de toekomstige milieunormen voor vervoermiddelen, kan deze vorm van inflexibiliteit van de binnenvaart in haar nadeel uitwerken.

Richtingen voor verder onderzoek

Vele zaken spelen een rol bij het verbeteren van de prestaties van intermodale binnenvaart, maar in dit proefschrift konden daarvan slechts enkele aan de orde worden gesteld. Dit proefschrift richtte zich vooral op de processen in de intermodale binnenvaartketen vanuit een operationele invalshoek en op de aanknopingspunten die deze processen bieden om de prestaties van het intermodale transportsysteem en de concurrentiekracht van dit systeem te verbeteren. Er zijn op uiteenlopende terreinen belangrijke onderwerpen te benoemen waar onderzoek een bijdrage kan leveren aan strategieën die de prestaties en concurrentiekracht van intermodale binnenvaart kunnen verbeteren, maar dichtbij de thema’s van dit proefschrift zijn drie richtingen voor verder onderzoek noemenswaardig.

In de eerste plaats is dit onderzoek dat een voortzetting is van het onderzoek waar dit proefschrift eindigt, namelijk verder onderzoek in het hub-and-spoke netwerk voor intermodale binnenvaart. Gezien de potenties van dit type netwerk om het marktaandeel van intermodale binnenvaart te vergroten, is nader onderzoek gewenst naar de mogelijkheden tot implementatie. De argumenten die in hoofdstuk 4 van dit proefschrift voor een hub-and-spoke netwerk werden genoemd, zijn gebaseerd op exploratief onderzoek. De haalbaarheid van bepaalde hub-and-spoke netwerkconfiguraties voor containerbinnenvaart zou door middel van een empirische analyse moeten worden gevalideerd. Deze analyse kan worden uitgevoerd op basis van case-studies waarin vooraf gedefinieerde hub-and-spoke netwerkconfiguraties, rekeninghoudend met de container volumes en de karakteristieken van de waterwegen in dat netwerk worden beoordeeld. Een andere mogelijkheid is een meer complexe analyse, waarin een hub-and-spoke netwerkconfiguratie het resultaat is van analyse van hub-and-spoke netwerkontwerpen, waarbij deze configuratie dan beoordeeld wordt. Voor een dergelijke analyse moet een model ontwikkeld worden in het domein van operationeel onderzoek. Deze aanpak levert in feite de best mogelijke configuratie op, gegeven de herkomsten en bestemmingen van containerstromen en de restricties die worden opgelegd door routekeuzes, de scheepsgrootte en kenmerken van de waterwegen. In deze netwerkanalyse moet ook het gebruik van duwboot-duwbakformaties in plaats van motorschepen gevalideerd worden, omdat duwboot-duwbakformaties ogenschijnlijk meer flexibiliteit bieden om de voordelen van dit type netwerk te benutten. Dat wil zeggen, het is eenvoudiger om de scheepsgrootte – het aantal duwbakken in de formatie – aan te passen aan het beschikbare transportvolume en de dimensie van de waterwegen op de spoke-verbindingen. Gelet op de belangrijke rol van de hub voor de prestaties van de binnenvaarttransportdiensten in hub-and-spoke netwerken zouden ontwerpstudies van terminals voor zo’n hub ook deel moeten uitmaken van dit onderzoek naar de haalbaarheid van het hub-and-spoke netwerk.

Een tweede richting voor verder onderzoek betreft de functionele en ruimtelijke structuur van het terminallandschap. Het is nog onduidelijk of grote terminals de voorkeur verdienen boven kleine terminals en, daarmee verband houdend, of het huidige terminallandschap compleet is of dat er nog ruimte is voor meer terminals. De conclusie in hoofdstuk 8 was dat er vooral argumenten zijn voor de ontwikkeling van een aantal kleine terminals, omdat zodoende de afstanden en daarmee ook de kosten in het voor- en natransport beperkt blijven. Deze kosten hebben namelijk een nogal groot aandeel in de totale kosten van de intermodale binnenvaartketen. Echter het argument voor grote terminals is dat er betere mogelijkheden zijn om ritten in het voor- en natransport te combineren, vanwege de grotere volumes die op de terminal worden behandeld. Deze grotere volumes zullen echter meestal ook gepaard gaan met grotere afstanden in de voor- en natransportritten. Het is interessant om deze afweging tussen de tegengestelde effecten van grote en kleine terminals te analyseren omdat daarmee de optimale schaal van een terminal voor efficiënt voor- en natransport kan worden bepaald.

De gewenste schaal van een terminal is ook ambivalent vanuit het perspectief van binnenvaartdiensten waarmee de concurrentiekracht van intermodale binnenvaart wordt versterkt. Enerzijds is er behoefte aan consolidatie van vervoerstromen op inland terminals, met name in relatie tot verbetering van de binnenvaartafhandeling in zeehavens, om daarmee de kwaliteit van het achterlandtransport te verbeteren. Anderzijds zou zonder de bestaande kleine terminals het huidige marktbereik van de binnenvaart aanzienlijk kleiner zijn. Aangezien zowel grote als kleine terminals bestaansrecht hebben, lijkt het zinvol dat er een zekere hiërarchie in de inland terminals tot stand komt. Hoe zo’n terminallandschap functioneel en geografisch vorm moet krijgen is een interessant onderwerp, zowel vanuit wetenschappelijk perspectief als vanuit beleidsperspectief.

Een derde belangrijke onderzoeksrichting is de ontwikkeling van een intermodale laadeenheid waarmee de ontwikkeling van intermodale binnenvaart in de markt voor transport van continentale lading wordt ondersteund. Zowel standaard maritieme containers als 40-voet palletbrede containers kunnen wat betreft laadvermogen niet concurreren met de opleggers in het wegvervoer. Het laadvermogen van de oplegger is de norm voor de markt voor continentale lading die door het wegvervoer wordt gedomineerd. De bestaande wissellaadbakken daarentegen zijn moeilijker verticaal over te slaan en niet stapelbaar, hetgeen een voorwaarde is voor efficiënt binnenvaarttransport. Een intermodale laadeenheid die qua laadvermogen wel een concurrerend alternatief biedt, is de 45-voet palletbrede container die in de kustvaart steeds meer terrein wint ten koste van de oplegger. Deze container zou een optie voor intermodale binnenvaart kunnen zijn, maar deze containers kunnen vanwege hun breedte in beginsel niet efficiënt worden beladen in de huidige vloot van binnenvaartschepen, tenzij ze in combinatie met standaard maritieme containers worden vervoerd. Echter dit maakt de planning van de scheepsbelading complexer. Zo lang het aantal 45-voet palletbrede containers beperkt blijft is deze samenlading met standaard maritieme containers uitvoerbaar. Echter als deze 45-voet container de standaard zou moeten worden voor de ontwikkeling van de continentale intermodale binnenvaart, en deze containers op grote schaal worden vervoerd, zou de breedte van de schepen moeten worden aangepast. Gezien de lange levensduur van schepen is zo'n aanpassing in de vloot een moeilijk en langdurig proces. Om intermodaal vervoer in Europa te stimuleren heeft de Europese Commissie in 2004 een richtlijn voorgesteld voor intermodale laadeenheden die tot een betere uitwisseling van laadeenheden tussen vervoerswijzen zou moeten leiden. Door tegenstrijdige belangen van de vervoerswijzen (binnenvaart, spoor en kustvaart) ten aanzien van afmetingen en stapelhoogte van zo'n laadeenheid, is een standaard voor zo'n Europese intermodale laadeenheid er nog niet gekomen. Er valt op dit terrein nog werk te verzetten om een doorbraak te bereiken die leidt tot een daadwerkelijke multimodale intermodale laadeenheid, waarmee de ontwikkeling van het intermodale transport over land wordt ondersteund.

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