A new hinterland transport concept for the port of Rotterdam: organisational and/or technological challenges?

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Abstract

For container ports and their terminals to remain competitive and to handle the anticipated growth there are huge challenges to increase their productivity, to reduce the spatial pressure and congestion and to improve their hinterland accessibility. These challenges support the idea to consider or re-consider port concepts aimed at a different philosophy regarding hinterland transport operations. This operating approach assumes that the 'port entry' is shifted to an inland location. This location acts as a regional collection and distribution point for trucking operations, but should also be equipped to provide a rapid transfer to and from the port, to support a fast movement of containers through the port, and to avoid long storage in the port. The shift of 'port entry' can be accompanied by moving - beside container storage - also a number of other activities to an inland site that traditionally take place in the seaport, such as stuffing and stripping and warehousing, but possibly also customs clearance. This paper explores the opportunities of such a hinterland transport concept for the port of Rotterdam by focusing on the type of transport system to operate this hinterland concept. It discusses the possibilities and limitations to use existing conventional intermodal modes, i.e. rail and barge transport, and evaluates the potential role of new transport technologies in such a hinterland transport concept.

Introduction

During the last two decades worldwide container transport has grown very rapidly. Globalisation, economic growth and the rising Chinese economy have boosted flows of goods from one continent to another and this has significantly affected the development of container transport. From 1985 to 2005 global container transport grew on average by 10% per year, while the growth of general cargo was just 3,8% annually. The expected pace of growth of container flows from now to 2015 is still 7,5% per year. The increasing numbers of containers, the creation of global shipping alliances and the trend to post-Panamax container ships are putting much pressure on seaports.

Lately port congestion has become, particularly in Europe and United States, a major issue for shippers and their service providers and seems of structural nature as maritime terminals continue to struggle with ever-increasing container flows. Many actors in the chain are faced with the consequences of the congestion. Deepsea carriers may be charged additionally for missing berthing slots in subsequent ports and confronted with higher fuel costs to make up or readjust schedules. Container stevedores have difficulties to carry out their plans because of delayed arrival of deepsea vessels and hinterland operators are affected too because intermodal transfers are also delayed, i.e. containers miss their feeder, train or barge connection. Such delays result in huge costs for shippers and consignees and make the supply chain highly unreliable.

The rise of cargo from China has been identified as the main reason for current congestion problems. However, it is widely believed that a lack of investment, planning and outdated practices in terminals have significant contributed to the problem (Van der Jagt, 2005). Furthermore, it is recognised that part of the congestion problem lies with the policy of terminals to offer a long free storage of containers, as a way to attract and keep customers. In US the average length of time a container remains on a marine terminal is about 6 to 8 days (Garcia, 2006); in Europe the dwell time is about 3 to 5 days (Günther and Kim, 2006).

Many ports are responding to the increasing containers volumes either by upgrading existing terminals or developing ambitious port terminal expansion plans. However, this is only part of the solution. For many seaports space limitations and environmental regulation, because they are located in the vicinity of metropolitan areas, are likely to restrict future expansion. Furthermore, redevelopment does nothing to reduce road freight flows and congestion around terminals, they merely add to an already serious problem (Slack, 1999).

Increasing container throughput in the ports also leads to increasing transport volumes in their hinterlands and this has also brought the issue of capacity and quality of the hinterland transport system to the fore. Containerisation has increased the geographical market coverage of seaports substantially and as a result the hinterlands of seaports have transformed from captive regions to contestable regions (see e.g. De Langen and Chouly, 2004; Notteboom, 1997). That is to say, ports are much more in competition to serve the same inland areas and this is especially the case for the major Westeuropean seaports (Le Havre, Antwerp, Rotterdam and Hamburg) where the distance of these ports to major cargo generating inland areas is not a very distinguishing factor. These circumstances make hinterland accessibility increasingly important for the competitiveness of a seaport. Basic requirement of a successful, competitive hinterland transport system is the ability to offer services, which are cost-effective, reliable and have a short transit time. In addition, the system should be able to serve many destinations and as a part of these criteria the interface between the seaport terminal and the hinterland modes should be efficient, fast and reliable.

The development of intermodal hinterland transport (rail and barge), enabling large-scale transport services, is gaining importance to keep the port accessible by shifting cargo way from the congested roads to the railways and waterways. In Europe, US and Asia, intermodal transport gains political importance (Nemoto et al, 2005). In many seaports road transport is still pre-eminently the major hinterland transport system, but further accommodating the container growth by road transport is not a real option: road infrastructure in and to the seaports reach their capacity limits and heavy congestion not only occurs on the roads, but also at terminals. In addition, the environmental and social impacts of road transport are subject to strong debate about the future role of road transport. On the other hand, many ports are also faced with different restrictions in railway capacity in the hinterland and expanding capacity is an expensive and often long-term process. Barge transport can be an attractive alternative, for some major seaports in Europe (Rotterdam, Antwerp) and US (New York/New Jersey) but most seaports are not connected to a well-developed waterway network.

For container ports and their terminals to remain competitive and to handle the anticipated growth there are huge challenges to increase their productivity, to reduce the spatial pressure and congestion and to improve their hinterland accessibility. These challenges support the idea to consider or re-consider port concepts aimed at a different philosophy regarding hinterland transport operations. This operating approach assumes that the ‘port entry’ is shifted to an inland location. This location acts as a regional collection and distribution point for trucking operations, but should also be equipped to provide a rapid transfer to and from the port to support a fast movement of containers through the port and to avoid long storage in the port. The shift of ‘port entry’ can be accompanied by moving - beside container storage - also a number of other activities to an inland site that traditionally take place in the seaport, such as stuffing and stripping and warehousing, but possibly also customs clearance. The idea described here has much in common with the concept of off-dock rail terminals acting as an intermodal interface centre between the seaport and remote hinterland destinations, which have varying success in the US. It also strongly refers to the concept of satellite terminals (Slack, 1999) focussing on the role the inland terminal to relieve the seaport terminals by transferring common functions performed in the port to the inland terminal, rather than on the transport system connecting the seaport with this satellite terminal.

To recapture, a key element of this hinterland transport concept is the organisation of transport between the marine terminals and the inland terminal. Transport between these locations should perform more or less like an internal transport system, and could take different forms of intermodal transport (i.e. rail or barge). However, in view of the current and prospective shortcomings of the existing hinterland transport systems it is suggested to consider also more advanced forms of container transport. Some of these advanced technologies have been proposed for instance by Dimitrijevic and Spasovic (2005), James (2005) and James and Gurol (2006) for the port of Los Angeles/Long Beach.

In this paper we will explore the opportunities for such a reorganisation of hinterland transport for the port of Rotterdam by focussing on the type of transport system to operate this hinterland transport concept. In particularly the potential role of new transport technologies is addressed. The paper starts with a brief overview of the present situation in the port of Rotterdam. Next the opportunities and limitations of the existing intermodal modes to play a role in this hinterland transport concept are presented. In addition, specific arguments to consider alternative transport systems are discussed. A brief overview of innovative alternative transport technologies suitable for container transport is given and the potential feasibility to implement these technologies is explored. The paper ends with conclusions.

A closer look at the situation in the port of Rotterdam

Rotterdam is the largest container port in Europe. In 2005 container throughput was 9,3 million TEU, closely followed by its direct competitors Hamburg (8,0 million TEU) and Antwerp (6,5 million TEU). In the period 1995 to 2005 growth of throughput in Rotterdam increased by 95%. The total container volume is expected to increase another 70% to 15,9 million TEU in 2020 (Municipality of Rotterdam and Port Authority Rotterdam, 2004).

The western part of the seaport (Maasvlakte area) is directly located near the sea, which provides a good accessibility for the largest contemporary container vessels (8,000 – 13,000 TEU). Even larger vessels (vessels of 18,000 TEU which are envisaged for the future) can be handled. This increasing throughput volume and vessel size – resulting in also larger call sizes - will increasingly put pressure on the terminal and hinterland performance.

Container activities in the port of Rotterdam are spread over the port area, but in a clustered way. There are three clusters: Eem/Waalhaven, Botlek and Maasvlakte. The maximum distance between these clusters is about 40 km. Deepsea container handling is concentrated in Eem/Waalhaven (35%) and Maasvlakte (65%). In the future the Maasvlakte will play an even more important role, because port expansion is planned at Maasvlakte. The container handling capacity of the port will increase from currently 10,3 million TEU to 16 million TEU in 2013, when the expansion of Maasvlakte should be completed.

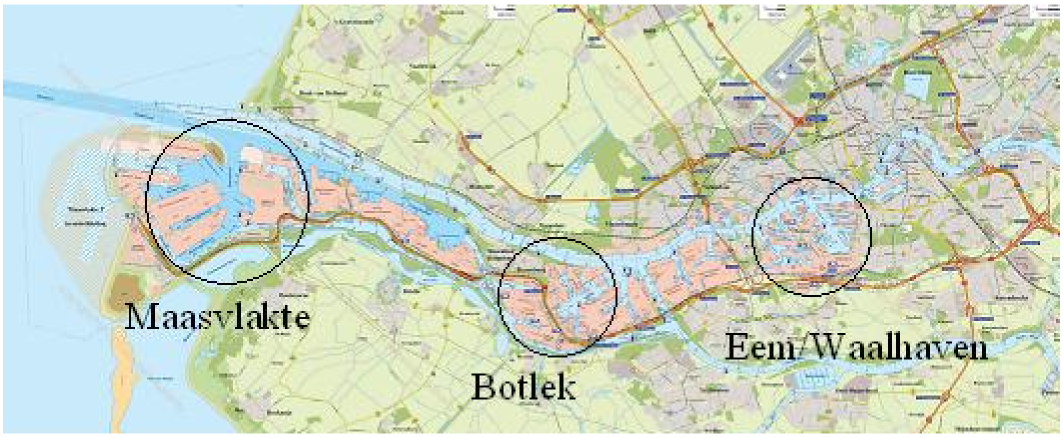


Figure 1 Location of container handling activities in the port of Rotterdam

Source: adapted from Port Authority Rotterdam

The deepsea stevedore activities are dominated by two large companies (ECT and APM terminals). In addition, some small stevedore companies are involved in container handling (Hanno, Uniport and Rotterdam Short Sea Terminals). As the Maasvlakte expansion is completed, some other companies – most likely shipping lines – are also expected to perform container handling.

The ECT Delta terminal at the Maasvlakte was the first container terminal in the world where a high degree of automation, i.e. robotized processes, was introduced. Container transport from the quay to the stack is fully automated, using unmanned, automated guided vehicles (AGV's), and the stacks are equipped with automated stacking cranes (ASC's). After its introduction in 1993 the performance of this automated system has been improved ever since and it will also be applied at other terminals to be constructed at Maasvlakte.

In hinterland container traffic road transport plays a dominant role. Its current share in the modal split is about 60%, while barge and rail have a share of 31% and 9% respectively. Although the share of road transport has been more or less stable during the last five years (see table 1), the number of containers transported by road still increased from 1,870,000 units in 2001 to 2,450,000 boxes in 2005 (a growth of 31%) in this relatively short space of time.

Table 1 Modal split in container hinterland transport of the port of Rotterdam, 2001 – 2005 (in 1,000 containers and in percentage)

	2001		**2002**		**2003**		**2004**		**2005**	
	cont.	%	cont.	%	cont.	%	cont.	%	cont.	%
Barge	925	30	1,089	32	1,102	31	1,188	31	1,280	31
Rail	258	9	302	9	336	10	358	9	380	9
Road	1,870	61	2,002	59	2,083	59	2,344	60	2,450	60
Total	3,053	100	3,393	100	3,521	100	3,890	100	4,110	100

Source: Port Authority Rotterdam

The only hinterland route by road consists of the A15 highway, connecting the port of Rotterdam with the hinterland in eastern direction. The capacity expansion of this highway did not keep up with the persistent traffic growth of road transport and this highway is increasingly faced with congestion problems both inside and outside the port area. The fact that the A15 is the only available major road giving access to the port not only endangers future accessibility, but also makes it very vulnerable (IJsselstijn et al., 2006). Many containers transported by road have a regional origin or destination, but are also transported nation-wide, but even in international traffic the role of road transport is significant.

Until now rail transport has played a modest role in container hinterland traffic for several reasons, including a lack of rail capacity. Currently a new dedicated freight rail line (the Betuweline) connecting the port of Rotterdam with the German hinterland is being constructed and is planned to be operational in 2007. This offers opportunities for substantial growth of rail transport if rail operators can offer services at competitive freight tariffs and quality. Rail container traffic is predominantly international traffic at distances ranging from 150 km (to Antwerp, Belgium) to 1100 km (North Italy) and more.

Barge transport has dramatically gained importance as a hinterland transport mode. The ability to offer cheap and reliable services has attracted the interest of shippers and carriers in barge transport and explains the significant growth of container barge transport since the mid eighties. 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. About 40% of the total volume consists of Rhine river traffic and hence has its origin or destination in Germany over a distance of 200 up to 900 km from the port of Rotterdam. About 35% is container barge traffic between the port of Rotterdam and Antwerp over a distance varying from 125 to 180 km. The remaining volume consists of national traffic with a rather dispersed pattern of flows and at distances ranging from 50 to 250 km.
All these container movements are still a huge burden on the rail and road infrastructure in and around the port. Assuming a constant modal split in 2020, 7 million(!) TEU has be transported on the A15 and 1 million TEU over the Betuweline, and taking the aimed modal split of the port authority of Rotterdam still 4 million TEU would be transported over the road and 2,3 million TEU over the Betuweline.
This means that within the port authorities ambition in 2020 about 3 million TEU must be shifted from road to rail and other modes. The extended gateway concept in combination with intermodal transport is a possible option to fulfil this ambition.

Transport options within extended gateway concept

The bottom line of the extended gateway concept is that the container transhipment function in the seaport is separated from the container storage and sorting function. The container storage and sorting function should be transferred to strategic located inland locations, where space is not restricted. These locations can be sites just outside the seaport (which much resembles the well-known concept of off-dock terminals) or they can be situated at greater distance in the hinterland, i.e. closer to the market than the seaport (which could give the concept some additional added value, but could also have some drawbacks). Together with container storage also a number of other activities that traditionally take place in the seaport (for instance customs), but also logistical added value services (e.g. warehousing) can be transferred to these inland sites. This relieves the spatial pressure in the port.

A key element of this concept is however the transport connection between seaport and inland terminals. Low cost, fast and reliable services are required to facilitate this concept. As a result of good direct connections these hinterland sites can profile themselves as a real extension of the mainport (gateway): the ‘port entry’ is virtually shifted to an inland location. This means that it provides a way to tie up cargo flows in the hinterland to the seaport, and so it can improve the competitive position of the seaport.

Depending on the location of these extended gateways (close to the seaport or at greater distance) these inland terminals can play a larger or smaller role in the function of sorting containers, i.e. the inland terminal act as the entrance or exit for container flows from and to the port. Temporarily stacking of containers, reorganising container batches and so on can take place at the inlandterminals. Outbound containers are hold at the inland terminal until needed for shipping. Inbound containers are sent directly when offloaded to inland terminals. In taking over this function from the terminals in the seaport it contributes to easier and more efficient handling of containers in the seaport and hence also improves terminal productivity of marine terminals. In its role as a sorting center (hub) the extended gateway can further stimulate the development of intermodal transport. Today, inland terminals already play this role to a certain level. In the extended gateway-concept, they become an integral part of the seaport operation. By moving port operations to an inland location, more space becomes available for dock-related activities in the port.

Figure 2 major inland terminals for the Port of Rotterdam

Opportunities and limitations of existing conventional modes: rail and barge

One of the merits of rail and barge transport is to offer large-scale operations and hence low unit transport costs. This holds in particular for barge transport. The presence of an extensive national and international waterway network with good navigation conditions, among which the Rhine river, enables to operate vessels of 90 to 208 TEU capacity in the national trade to 400 TEU or even more in the Rhine river and Rotterdam-Antwerp trade. The capacity of trains is generally limited to 90 TEU, because of the maximum train length (700 meter) and the impossibility of double stacking.

The average speed of both modes, however, is limited (about 15-20 km/h). With respect to barge transport this is inherent to system characteristics, but regarding rail it is caused by operational procedures and transport policies.

In the current situation barge vessels have to call at many marine terminals (and container depots) spread over the whole port area when they visit the port of Rotterdam and because they are frequently faced with waiting times at these terminals (because deepsea vessels have priority in handling), barge handling in the port is a time-consuming and hence rather inefficient process. It affects not only the productivity of the barge operators negatively, but also the marine terminal productivity, because the call size of these barges is generally small.

Container trains are handled at Rail Service Centers (RSC) at the Maasvlakte and Eem/Waalhaven. RSC Maasvlakte has a capacity of 8 tracks. Here all trains of different rail operators (e.g. ERS, Railion, Hupac, Kombiverkehr) for all different hinterland destinations have to be formed. To perform these processes the dwell time of trains at the terminal is long and hence this is also inefficient. The large number of trains negatively affects the optimal use of rail infrastructure capacity. While the rail infrastructure requires space at the port that cannot be used for port activities. These kinds of inefficiencies are expected to increase if shipping lines operating their own deepsea terminal are likely to claim an own on-dock rail facility.

To overcome these problems it is conceivable to develop large capacity shuttle services by rail and/or barge from marine terminals to an off-dock terminal nearby the port of Rotterdam or even to a more distant located inland terminal, which acts as a sorting point for flows between marine terminals and hinterland origins/destinations. Some barriers might exist in realising such dedicated intermodal services:

Containers are handled additionally (additional time-consumption and costs and still a need for short-term stacking space), unless additional time-consumption can be compensated by f.i. direct transhipment to trains/barges.

Large capacity services focus on low frequent pickup and delivery of containers in large batches and at low speeds. Perhaps these are not the most suitable characteristics for an extended gateway concept. In new ports concepts, like the extended gateway when the ‘port entry’ is shifted to an inland location, highly reliable and on demand transportation between the port and the inland terminals plays an important role. Existing rail and barge container transport systems do not seem able to deliver such a service. Moreover, large capacity shuttle services require large terminals. In particular, rail terminals occupy large areas of land at a location. However, the biggest driver for looking at new transport technologies will remain emerging and increasing problems faced by using the existing modes. Although the capacity of the hinterland infrastructure of the existing modes (waterways and rail lines, the Betuweline in particular) does not raise problems in near future, the numbers of trains and barges to be handled in long term are unprecedentedly. If the modal split, which the port of Rotterdam aims for in 2020 could be realised (rail 18%, barge 40% and road 42%) the number of barges and trains to be handled would become huge. Based on a capacity of just 90 TEU per train about 490 trains need to be handled per day and taking an average size of 200 TEU for a barge vessel still 25.000 vessels per year or 490 vessels per day need to be handled. This scenario is very likely to be efficient, if ever feasible at all.

Overview of potential promising innovative/automated transport technologies

Automated freight transport is still in its infancy. Except for internal transport systems in factories and at some container yards, applications of automated freight transport are still rare. However, the benefits of automation (such as reduced labour cost, 24-hour continuous operations and higher reliability) have seriously raised the interest lately. Encouraged by successful applications in public transport (people movers) and industry, during the last 10 to 15 years research and development in transport automation has substantially increased and many new technologies have been proposed and elaborated for various types of applications and are in different stages of development (Konings et al., 2005; Rijsenbrij et al., 2006). This section draws most information from these documents. For the purpose of this paper we concentrate on discussing transport technologies that could be considered for hinterland transport of containers, over medium distances (50 – 150 km), and be applied within a relatively short term (within 5 years). The types of systems discussed are:

- Automated Trucks and Multi Trailer Systems
- Automated Trains
- Automated Barge Handling Systems
- Automated Capsule/alternative rail Systems

After a brief introduction of the alternative systems, the focus will be on the potential performance (capacity, speed, cost/unit, etc) an applicability of the systems in marine terminal - off-dock terminal connections.

Automated Trucks and Multi Trailer Systems

There have been several projects focussing on the automation of trucks in e.g. Japan (Dual Mode Truck), the USA (PATH) and Europe (CombiRoad, Chauffeur and others). Figure 3 shows pictures of test done in the Netherlands (CombiRoad on the left) and in the USA (PATH on the right). Automated trucks can be used to transport containers over short as well as longer distances (comparable with normal trucks), and could be applied in a relatively short time. The demonstrations have shown the technical feasibility.

Figure 3 Automated trucks: Combi Road (left) & PATH (right)

Although not (yet) automated, developments in Multi Trailer Systems (MTS) could also be of interest. MTS systems have been in use for many years within the port area of Rotterdam (Figure 4 left). Some trials proved the technical feasibility of the automated road train, where one Automated Guided Vehicle (AGV, in use at the ECT Delta Terminals in Rotterdam) pulled a set of 5 trailers (Figure 4 right).

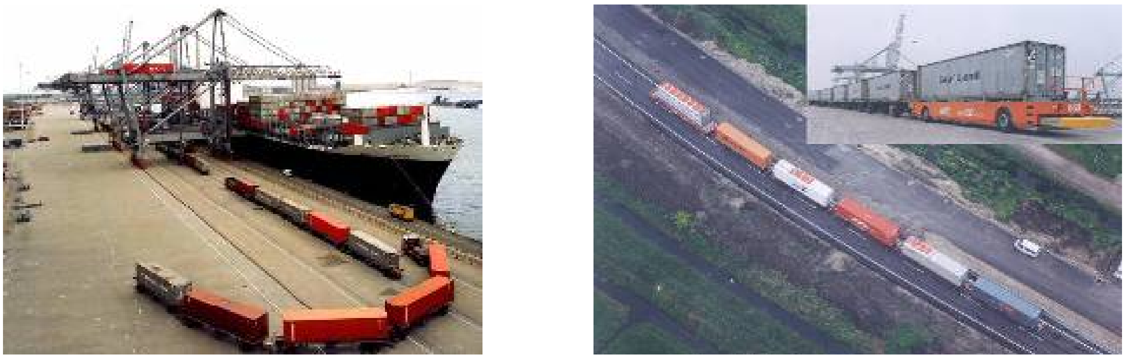


Figure 4 Multi trailer systems

The potential performance of automated trucks, possibly combined with multiple trailers, is high. The trucks can run close together, 24 hours a day. Even with relatively low speed of 3 m/s (about 11 kilometres/hour) the theoretical maximum capacity of a single lane could be around 1,000 TEU per hour or 24,000 TEU per day (assuming a 2 TEU truck is 18 meters long and the average distance between trucks is a little over 3 meters). With increasing speeds (perhaps even up to 90 km/hour) the theoretical capacity will further increase. Furthermore, when compared with tradition trucks, the operational (labour) costs can be reduced significantly. The eventual cost per TEU will of course greatly depend on the required investments and use of the system.

Although the tests have proved the technical feasibility, implementation remains a major issue. Up to now, automated trucks require a separate (dedicated) lane, and should not be mixed with normal traffic (due to safety and legal issues). Although one could build a new road or reserve and adapt a specific lane of the existing road infrastructure, this would be expensive and only viable if there is a sufficiently large market. Furthermore, as is often the case with new systems, there is the so called “chicken and egg” problem. Who will invest in new infrastructure if there are no vehicles to use it; and who will invest in new vehicles if there is no infrastructure to use it on. Therefore, a first implementation could be expected between two locations, relatively close together, with large cargo movements between them and within a relatively controlled environment e.g. port areas (Rijsenbrij et al. 2006). For the shorter distances (tens of kilometres) the currently operational AGV’s could also be considered. They can travel 3 - 5 m/s and the interface or integration of the hinterland transport system with the marine terminals currently using these AGV’s for internal transport would then be relatively easy and would not require additional handling space. Terminals which do not use AGVs would of course have to develop an exchange area where container can be loaded/unloaded on/of the AGV. For longer distance (up to 150 kilometres) faster automated trucks should be considered. Automated trucks and automated Multi Trailer

Systems would most probably require and additional loading/unloading area and several other adaptations at the marine terminal. Application of these types of systems on the terminal should however not lead to major problems.

Automated Trains

The most well known operational automated rail guided vehicles are probably the automated metro systems in e.g. France and Japan (Figure 5 left). These are however not used for freight. There are, to our knowledge, no automated freight trains in operation today. However, as with automated trucks, there have been developments in the automation of freight trains. Figure 5 (right) shows a picture of a prototype developed by Siemens in Germany called CargoMover. As with automated trucks, the potential speeds and distances can be compared with normal trains.

Metro

CargoMover

Figure 5 Automated trains

The CargoMover is a redesigned, self-propelled, automated flatbed rail freight car with a payload of up to 60 tons. It can transport containers and swap bodies and was designed for local and regional freight transport, of up to 150 km with a top speed of 90 km/h. The potential performance of such a system, in term of speed and capacity on a single track, could be comparable with automated trucks and multi trailer systems. The automated rail cars could run in single formation (comparable with trucks) or combined in trains. Automated trains can also be regarded as proven technology. This is not only demonstrated by the CargoMover developed by Siemens, but also by the different automated metro systems that have been in operation for many years already, and proving very reliable. However, as with automated trucks, automated trains require a dedicated infrastructure. Mixing fully automated freight trains with manned passenger trains on the same track will most probably not be accepted, at least not in the near future. When compared to road infrastructure, rail infrastructure can however be characterised as more “enclosed” or dedicated. This could be beneficial for the shorter-term implementation. First implementations of automated freight trains could be realized using existing (less- or unused) tracks that can be reserved for/ dedicated to these automated freight trains (Rijsenbrij et al. 2006). It is however questionable if such tracks are available in the Port of Rotterdam. Compared to automated trucks, integration of rail-based systems in the marine terminals could prove more difficult and require more space, especially if there is no existing rail infrastructure present. In any case it will require rail connections and rail infrastructure on the terminals for loading/unloading containers. Compared to conventional trains, the operation could however be improved (require less space for loading/unloading), as automated wagons do not have to wait for the entire train to be loaded/unloaded.

Automated Barge Handling Systems

Barge Express is an integrated concept for container barge transport and handling: barges are equipped with cell guides to facilitate an automatic loading and unloading process. The concept has been proposed as a solution to improve the cost performance and quality of barge transport as a hinterland mode for container transport. One part of the idea is to reduce the sailing costs by 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) that can only sail on the major hinterland waterways of Rotterdam. The other part of the idea is to reduce container handling costs (as these costs are relatively high in the container barge transport chain) by automation of the loading and unloading process (see Figure 6).

The (un)loading process is supported by computers, automated quay cranes, automated guided vehicles (AGV’s) and automated stacking cranes (ASC’s). 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 AGV’s arrive at the Barge Express terminal to load a push barge, the released AGV’s 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 AGV’s and ASC’s. 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 push barges can offer one daily service in two directions up to a distance of 80 km, which means a capacity of 1248 TEU.

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, 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.

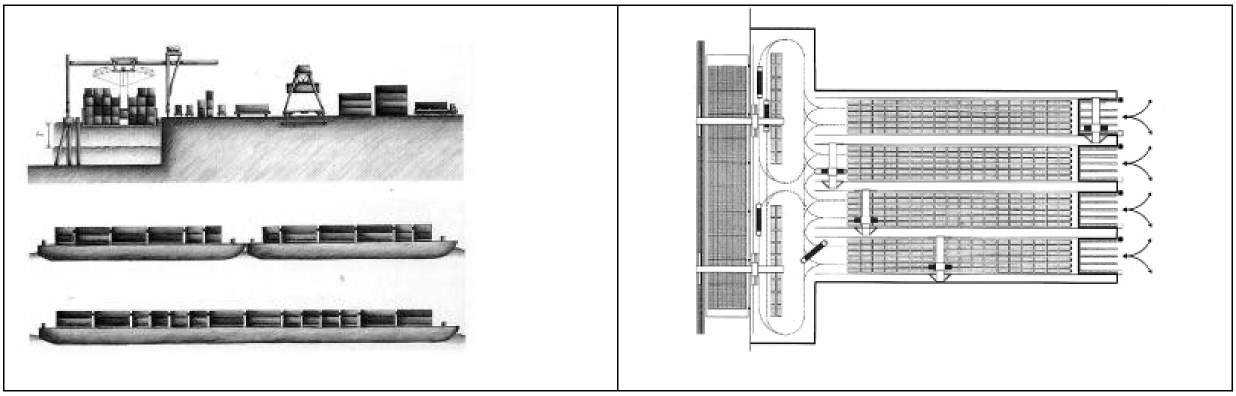
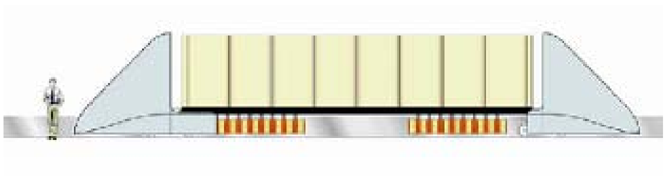


Figure 6 Barge Express system (vessels, cranes and terminal lay out)

Automated capsule / alternative rail systems

Perhaps less known are developments in so called capsule systems. Although most of the earlier developments focused on capsule systems for transporting relatively small loads (e.g. parcels or pallets) through tubes or tunnels, there are also concepts that can accommodate containers, swap bodies or even semi-trailers. Figure 7 (left) shows a concept developed by the CargoCap consortium in Germany. Figure 7 (right) shows the SAFE Freight Shuttle concept developed by Texas Transport Institute in the USA (Roop, 2003). Although these "capsule" systems could be used within a tunnel or tube, they are also positioned as transport systems that could operate outside a tunnel or tube. Both systems are presented as rail guided systems, although not by traditional rail.

Cargo Cap Concept



SAFE Freight Shuttle Concept

Figure 7 Automated capsule / alternative rail systems

The CargoCap concept was developed for transporting swap bodies, semi-trailers and containers with a maximum length of 45’ between ports and their hinterland, using tunnels or dedicated infrastructure. The SAFE Freight Shuttle concept is proposed as a new mode of transport for the truck movements to and from Mexico through Texas. Both would be electrically powered, the SAFE freight shuttle by an Linear Induction Motor, and would be able to reach maximum speeds of 80-90 km per hour. With respect to speed and capacity, the capsule concepts should be comparable with automated trucks and automated trains. Furthermore, as with the other automated concepts, the automated capsule systems for containers also require a dedicated infrastructure. However, this dedicated infrastructure is not compatible with current rail or road infrastructure and would have to be newly developed, which could prove problematic from an implementation / integration point of view.

Automated capsule systems for containers are still in the conceptual design phase, up to now no working prototypes have been built. Although the concepts themselves have not been “proven”, the proposed technology or components are not new. As such the concepts could be considered to be technologically feasible. Ports in the USA have expressed their interest in the concept. Whether such a system could be applied within 5 years however remains to be seen.

System evaluation

In evaluating the feasibility to implement new technologies many issues play a part (Dimitrijevic and Spasovic, 2005; Weber and Seibt, 2005; Dahlgren, 2005). First of all it is the performance of the system that matters. The new transport facility should offer the users a relative advantage over the current facilities. In the end the shippers should gain with new operations in terms of transport tariff, transit time, reliability, flexibility, sensibility to cargo damage etc.. Many of these criteria will also hold for other actors in the hinterland transport chain (e.g. inland transport operators, container stevedores), because their own operations will be affected by such a new system.

Critical factors regarding the performance of a transport system between the marine terminals and off-dock terminals in the hinterland are:

1. Capacity: it concerns large flows, which have to be moved smoothly to and from the port to an inland off-dock terminal 50-150 km from the port.
2. Availability, reliability and continuity. Another requirement is that the containers must be moved on demand and must arrive as planned.
3. Speed: speed is of importance but is not a particularly critical factor, as long as distances are not too great and reliability and availability is guaranteed.

Another critical issue for implementation of a new transport technology are of course the financial conditions, such as the level of investment costs, the exploitation costs (including maintenance) and the revenues. The feasibility of a new system will in general strongly depend on its economic feasibility.

In addition there are many other impacts, which may be less important from a commercial, private perspective, but are highly relevant from a social point of view, such as environmental and socio-economic impacts. These so called external effects, which are also largely non-monetary, are gaining importance in project evaluations and particularly in investment projects where governments have to participate financially.

Part of the system performance is also the compatibility with the existing system (i.e. its intermodal qualities), from a technological and organisational perspective. A transport system developed to move containers between marine terminals and an inland location requires a seamless interface with both the operations at the marine terminals and the inland terminal. This assumes appropriate transhipment and exchange facilities and organisational co-ordination.

Other aspects of system performance are its technology reliability, i.e. risk of failures and safety. The exclusion of the human factor in automated processes in principle increases the safety level (internal safety). On the other hand however it can bring along other safety risks, in particular when infrastructure is used for both automated and manual operations, but also in the case that automated operations take place on dedicated infrastructure in a public environment (external safety).

Finally, the extended gateway concept introduces an extra handling in the transport chain to and from the port. This means that handling costs and time loss must be minimal and or compensated in the transport move.
So, at the marine terminal: no extra handlings costs and internal terminal transport are preferred. For example, trains that can be loaded directly at the dock is an optimal solution. With barges one can think of a floating stock (barges in which containers are collected and from where containers are directly transferred from ship on barges). Floating cranes are useful for direct shipment from vessel to barge. Also, no extra handling costs and time-loss are preferred at the off-dock terminal in the hinterland.

To assess the potential feasibility of the transport technologies described in the previous section the following criteria have been used:

- System performance: capacity, speed, cost/unit, compatibility, technological reliability (proven technology) and safety;
- Financial impacts: investment costs and operational costs;
- Environmental impacts: land requirements, noise, air pollution and energy consumption.

As this paper is a first exploration of possible technological options to develop this new hinterland transport concept all impacts of the different technologies could not be assessed in detail. As a result the evaluation is rather qualitatively than quantitatively. In Rijsenbrij et al. (2006) the feasibility of new innovative concepts are described in more detail.

Can current modes of transport provide the right service for extended gateway concepts?

When we compare the current modes the following conclusions are drawn. Current modes of transport are proven and use existing infrastructure but they have drawbacks.

Road transportation is quite flexible, but is not very reliable due to congestion on the roads to and from the ports. However, in a situation with dedicated lanes for trucks or multitrailers and additional capacity, it is an interesting option.

Transportation by barge and rail is based on providing large capacity services. Large capacity services focus on low frequent pickup and delivery of containers in large batches and at low speeds. Perhaps these are not the most suitable characteristics for an extended gateway concept. Rail and barge are limited by their speed. However at short distances and smaller batches, transport services by barge and by rail can be interesting though. Smaller batches and short distances lead to shorter turnaround times. This saves time and costs.

Will innovative/automated transport technologies be the answer for implementing extended gateway concepts?

In this study we looked at automated systems.

- Automated Trucks and Multi Trailer Systems
- Automated Trains
- Automated Barge Handling Systems
- Automated Capsule/Alternative Rail Systems

Automation of transportation lead to labour costs reduction but requires a dedicated infrastructure, an extra cost factor to consider. The studies show very positive results in terms of performance and costs. We did not include the expected costs for each of the systems in this paper, but they can be found in the report (Rijsenbrij et al., 2006).

The extended gateway concept is an interesting field of application to test and implement these systems to prove the commercial viability. In particular, because it is a point-to-point connection, and is much easier to set up for new innovative systems, than regular transport.

Also, these systems have performance characteristics that are very promising. With a dedicated lane, they are able to provide a reliable and continuous service 24 hours a day. There are some differences in speed, capacity and flexibility between the systems. But, at this moment, it is difficult to determine what the exact criteria are regarding reliable, flexible, fast and cost efficient transportation in the extended gateway concept.

Conclusions

Existing transport modes will always play a role in the movement of containers to and from the ports. Current congestion problems in ports and on the infrastructure near ports force us to look at new port concepts. New port concepts in which the 'port entry' is shifted to an inland location, accompanied by a movement of all kinds of operations, as buffering, stripping and stuffing and warehousing, contribute to solving the port problems, such as congestion and lack of space.

Very essential for these new concepts is that they requires highly reliable and on demand transportation between the marine terminal and the off-dock terminal. Any delays or loss of control within the system causes malfunctioning of the system.

For this reason we looked at new innovative systems, such as automated trucks and multi trailer systems, automated trains, automated barge handling systems and automated capsule/alternative rail systems. We found different test and demonstration projects in this area. All of these new systems fit well within the extended gateway concept. The two elements: a dedicated lane, meaning a flexible and full continuous service and transport automation, meaning labour cost reduction, are important assets for this concept.

We did not discuss the strengths and weaknesses of the extended gateway here, but there are some threads that need to be mentioned.

It speak for itself that shipping companies with their own terminal in the port, also want to work this way. First, in carrier haulage transport. The question is if merchant haulage transport also will move in that direction. Cooperation between shipping companies will make it more attractive, but it is doubtful of this will happen. A very important barrier is the diversity of flows and the drive of shipping companies to keep everything in their own hands.

As long as existing modes do not reach their limits, there is no serious driver for new concepts. In the US limitation of available rail capacity of rail can be such a driver. In the case of Rotterdam inland shipping still has a plenty of capacity on the waterways and the opening of the Betuwe railway line creates new railway capacity. For the short and medium term this link can be used to set up an extended gateway concept in the direction of the German hinterland, which forms the major hinterland corridor of the port of Rotterdam. However, in the long term when barge and rail traffic are also likely to put a burden on efficient handling in the port, because the number of trains and barges to be handled will be huge, innovative technologies will gain momentum.

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