# A Underground Logistics Systems (ULS): A case for the Deurganckdock?

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# Underground Logistics Systems (ULS): A case for the Deurganckdock?

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**Abstract**

During the last decade container traffic was the driving force behind the growth in cargo handling in the port of Antwerp. Between 1994 and 2004 container traffic almost tripled, enabling Antwerp to increase its market share in the Hamburg-Le Havre range. Moreover, various studies indicate that container traffic will continue to grow strongly in the years to come. In order to be able to respond to these growth perspectives and to safeguard the future position of the port of Antwerp as a container mainport, a new tidal container dock has been built on the left bank of the river Scheldt, the so-called Deurganckdock. This dock will lead to large flows of internal port container traffic between both banks of the river Scheldt. As the traditional hinterland transport modes offer insufficient capacity to accommodate the increasing number of containers, the idea of constructing a dedicated Underground Logistics System (ULS) to transfer containers between both banks of the river Scheldt seems tempting. In this paper a first analysis of different variants of such an ULS is presented.

**Keywords -** ports, container handling, hinterland transportation, Underground Logistics System

# 1. Introduction

The port of Antwerp is crucial for the growth of the Flemish and Belgian economy. In 2004 the port handled a total traffic of 152 million tons, of which 68 million tons (about 6 million teu) consisted of containerized cargo. Together with the industrial activity in the port this yielded a total direct employment of about 62,000 full time equivalents and a direct value added of 7.4 billion euro (National Bank of Belgium, 2005). It is therefore no surprise that the port of Antwerp is regarded by many as the engine of the Flemish economy.

This good track record of the port of Antwerp is not evident, however. The port has an important market share within the so-called Hamburg-Le Havre range in North-West Europe, thanks to its geo-economic location but in particular thanks to the high efficiency of its cargo handlers/stevedores, its excellent links with the hinterland and the continuous efforts to optimize its accessibility for seagoing vessels.

During the last decade container traffic was the driving force behind the growth in cargo handling in the port of Antwerp. Between 1994 and 2004 container traffic almost tripled, corresponding to an average annual growth rate of roughly 11%. This growth rate was significantly higher than the growth rate experienced by most other ports in the Hamburg-Le Havre range, which resulted in an increase of Antwerp's market share. Nowadays more than 75% of general cargo in the port of Antwerp is containerized. In the eighties this percentage was still below 30%.

Moreover, various studies[1] have indicated that container traffic will continue to grow strongly in the Hamburg-Le Havre range in the coming decade. In order to be able to respond to these growth perspectives and to safeguard the future position of the port of Antwerp as a container mainport, a new tidal container dock has been built on the left bank of the river Scheldt, the so-called Deurganckdock. This dock, which was partially taken into operation in July 2005, will increase the container handling capacity of the port of Antwerp to about 14 million teu per year when fully operational.

It goes without saying that the creation of additional container handling capacity on the left bank of the river Scheldt has a number of important implications, both with respect to the container transport within the port and with respect to the links between the port and its hinterland. First of all, the Deurganckdock constitutes another major "container concentration point" within the port of Antwerp, next to the existing terminals on the right bank (Europa and Northsea Terminal, Delwaidedock and to a somewhat lesser extent Churchilldock, see Appendix). Between these terminals large volumes of full and empty containers will have to be exchanged. In other words, the Deurganckdock will lead to large additional flows of internal port container traffic. Secondly, taking into account the geo-nautical and geo-economical location of the port of Antwerp with respect to its most important hinterland, the Deurganckdock can be expected to generate significant container flows between the left bank and the right bank of the river Scheldt. Estimates by the Antwerp Port Authority indicate that about 70% of containers to be handled at the Deurganckdock (transhipment containers excluded) have a hinterland origin/destination which necessitates a crossing of the river Scheldt.

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[1] E.g. in the context of the "ProSes"-project concerning the deepening of the Western Scheldt (ECORYS Transport, 2004 and ECSA, 2004). See also Ocean Shipping Consultants (2001).

The current hinterland transport modes (road transport, rail transport and inland navigation, which accounted for 60%, 9% and 31% of container transport between the port of Antwerp and its hinterland in 2002, respectively) offer insufficient capacity to accommodate the increasing number of containers during the years to come. Currently the Antwerp Ring road is already saturated during certain periods of the day. The closing of the Antwerp Ring road (the Oosterweel link, scheduled for 2010 at the earliest) will not be able to offer enough road capacity to support the growing hinterland transportation needs of the Deurganckdock. The situation is similar for rail transport: the capacity of the current rail tracks (adjacent to the Ring road and via the Kennedy tunnel) is already being used intensively, while the planned Liefkenshoek rail tunnel between both banks of the river Scheldt will not be finished until 2012. The inland navigation sector, to conclude, has already expressed its concern about the fact that not enough berthing capacity might be available at the future terminals of the Deurganckdock to handle inland barges (although the terminal operators have guaranteed that barges will be handled in an efficient way). Moreover, and this is crucial, inland barges have to pass the locks when transferring containers between the left bank and right bank or vice versa. Apart from an increase in costs, this also implies that the congestion at the locks will increase significantly. Hence, the capacity of inland navigation to transfer containers in a continuous way between both river banks is limited under current circumstances.

Taking into account the limited capacity of the three ‘traditional’ hinterland transport modes mentioned above, the idea of constructing a dedicated Underground Logistics System (ULS) to transfer containers between both banks of the river Scheldt seems tempting. In the present paper different variants of such a ULS will be compared, not only on a technological basis, but also with respect to the impact of their implementation on the existing container handling environment in the port.

This paper is organized as follows. In Section 2 an overview is given of the container traffic handled in North-West European ports during the last decade, with particular emphasis on the port of Antwerp. Section 3 then discusses the importance of hinterland networks for container ports. Next, Section 4 deals with the technological aspects of an Underground Logistics System to transfer containers between both banks of the river Scheldt. Section 5 contains the conclusions.

# 2. Container traffic in North-West Europe

## 2.1 Container traffic in the Hamburg-Le Havre range

The port of Antwerp forms part of the well-known Hamburg-Le Havre range in North-West Europe (see Figure 1). During the last decade this port range, which typically includes the ports of Hamburg, Bremen/Bremerhaven, Amsterdam, Rotterdam, Antwerp, Ghent, Zeebrugge, Dunkirk and Le Havre, witnessed an important increase in container traffic. As shown in Table 1 container traffic in the Hamburg-Le Havre range increased from 12.62 million teu in 1994 to 28.43 million teu in 2004. Hence, volumes more than doubled over a ten-year time span, representing an average annual growth rate of about 8.5%.

**Figure 1: The Hamburg-Le Havre range in North-West Europe**


**Table 1: Container traffic in the Hamburg-Le Havre range**

| | Container traffic in teu | | | | Average growth rates | | Market shares | |
|---|---|---|---|---|---|---|---|---|
| | 1994 | 2002 | 2003 | 2004 | 1994-2004 | 2002-2004 | 1994 | 2004 |
| Rotterdam | 4,539,767 | 6,506,310 | 7,106,779 | 8,280,787 | 6.19% | 12.82% | 35.98% | 29.13% |
| Hamburg | 2,725,718 | 5,373,999 | 6,137,926 | 7,003,479 | 9.90% | 14.16% | 21.60% | 24.63% |
| Antwerp | 2,208,173 | 4,777,152 | 5,445,438 | 6,063,747 | 10.63% | 12.66% | 17.50% | 21.33% |
| Bremen | 1,502,878 | 3,031,587 | 3,190,707 | 3,469,104 | 8.72% | 6.97% | 11.91% | 12.20% |
| Le Havre | 872,939 | 1,720,459 | 1,980,000 | 2,131,833 | 9.34% | 11.32% | 6.92% | 7.50% |
| Zeebruges | 609,307 | 958,885 | 1,012,674 | 1,196,755 | 6.98% | 11.72% | 4.83% | 4.21% |
| Dunkirk | 60,723 | 160,816 | 161,857 | 200,399 | 12.68% | 11.63% | 0.48% | 0.70% |
| Amsterdam | 89,608 | 44,966 | 44,511 | 51,904 | -5.31% | 7.44% | 0.71% | 0.18% |
| Ghent | 9,557 | 21,316 | 28,688 | 32,440 | 13.00% | 23.36% | 0.08% | 0.11% |
| **Range** | **12,618,670** | **22,595,490** | **25,108,580** | **28,430,448** | **8.46%** | **12.17%** | **100.00%** | **100.00%** |

Source: Port Authorities and own calculations

Table 1 clearly shows that growth in container traffic has been quite uneven among the different ports in the Hamburg-Le Havre range during the last decade. Container traffic in the port of Rotterdam, the biggest port in the range, increased from 4.54 million teu in 1994 to 8.28 million teu in 2004. This represents an average growth rate of 6.2% per year, which is less than the average growth rate for all range ports. As a result, Rotterdam's market share decreased from about 36% in 1994 to about 29% in 2004. During the same period, the port of Hamburg registered an average annual growth rate of 9.9% to attain a total volume of just over 7 million teu in 2004. Its higher-than-average growth rate enabled it to increase its market share from 21.6% in 1994 to 24.6% in 2004. In absolute volume terms, Hamburg decreased the gap with Rotterdam from about 1.8 million teu in 1994 to about 1.3 million teu in 2004.

Of the top-three container ports within the Hamburg-Le Havre range the port of Antwerp enjoyed the highest growth rate during the last decade. Whereas Antwerp handled 2.21 million teu in 1994 it breached through the 6 million teu-barrier in 2004. This near-threefold increase corresponds to an average annual growth rate of 10.6%. As a result, Antwerp was able to significantly increase its market share, mainly at the expense of Rotterdam. Whereas Rotterdam's market share was more than twice as high as Antwerp's share in 1994, the difference decreased to just 8 percentage points in 2004. Finally, with respect to the other container ports in the Hamburg-Le Havre range, it is worth mentioning that only Amsterdam saw a decline in container traffic between 1994 and 2004, while all other ports except for Zeebruges (slightly) increased their market share. However, prospects for Amsterdam and Zeebruges on the short-term look very positive (cf. infra).

As mentioned above, volumes on the trade route between Asia and Europe (the second largest container trade route after the Transpacific) increased substantially in recent years. According to Dynamar (2005a), westbound box liftings between the Far East and North-Europe increased from 4.61 million teu in 2002 to 6.34 million teu in 2004. This boils down to an average annual growth rate of 17.3%. Over the same period, eastbound box liftings (i.e. from North-Europe to the Far East) increased from 3.10 million teu to 3.77 million teu, representing an average annual growth rate of 10.3%. Hence, it should come as no surprise that ports in the Hamburg-Le Havre range, and in particular those ports which have strong links with Asia (Hamburg, Rotterdam and to a somewhat lesser extent Antwerp), enjoyed healthy growth between 2002 and 2004. As can be seen from Table 1, container traffic in the range ports increased from 22.60 million teu in 2002 to 28.43 million teu in 2004, which corresponds to an average annual growth rate of 12.2%. All container ports enjoyed average 'double-digit' growth rates during these two years, except for Bremerhaven and Amsterdam.

Moreover, it is expected that worldwide container trades, in particular the export trades originating from Asia, will continue to grow strongly in the years to come. Dynamar (2005b) estimates that the worldwide full container trade (all trade routes combined) will increase from 86 million teu in 2004 to 105 million teu in 2006, i.e. an average annual growth rate of 10.5%. As far as North-West Europe is concerned, Drewry Shipping Consultants (2005)[2] expects container traffic to increase from about 41 million teu in 2004 to nearly 50 million to in 2009. Hence, it should come as no surprise that most ports in the Hamburg-Le Havre range have embarked upon ambitious expansion plans in order to cope with increasing container volumes. Besides capacity increases of existing terminals, these plans also consist of the development of brand-new full container terminals (e.g. Euromax Terminal and Maasvlakte-2 in Rotterdam, Container Terminal Steinwerder and development of Moorburg-area in Hamburg, Deurganckdock in Antwerp, Container Terminal IV in Bremerhaven, Port 2000 in Le Havre, Albert II-dock South in Zeebrugge and Ceres Terminal in Amsterdam). When fully developed, these expansion plans should enable the ports in the Hamburg-Le Havre range to accommodate traffic growth in the medium- to long-term.

[2] Drewry's figures refer to all ports in North-West Europe, not just the ports in the Hamburg-Le Havre range. Hence, the figures should not be confounded with those from Table 1.

## 2.2 Container traffic in the port of Antwerp

Until last year, container traffic in the port of Antwerp was mainly handled on terminals located on the right bank of the river Scheldt, both within the dock system and outside the locks (see Table 2 and the Appendix). In 2004 the right bank terminals handled about 5.77 million teu or some 96% of the total container traffic in the port of Antwerp. The lion's share of this volume (5.34 million teu) was handled at the two River Scheldt terminals and at the terminals in the Delwaidedock. The Churchilldock handled about 0.16 million teu, while the remaining 0.27 million teu were handled at about 10 smaller terminals scattered throughout the dock complex.

**Table 2: Breakdown of container traffic in the port of Antwerp (2004)**

| | m teu | % |
|---|---|---|
| River Scheldt terminals | 2.81 | 47% |
| Delwaidedock terminals | 2.53 | 42% |
| Churchilldock terminals | 0.16 | 3% |
| Other right bank terminals | 0.27 | 4% |
| **Total right bank terminals** | **5.77** | **96%** |
| Vrasenedock terminals | 0.20 | 3% |
| Verrebroekdock terminals | 0.07 | 1% |
| Other left bank terminals | 0.00 | 0% |
| **Total left bank terminals** | **0.27** | **4%** |
| **Total container traffic** | **6.04** | **100%** |

Until the second half of 2005, the port area on the left bank did not boast any pure container terminals comparable to those on the right bank. The left bank volume of 0.27 million teu in 2004 (hardly 4% of Antwerp's total container traffic) was divided between various multi-purpose terminals in the Vrasenedock and Verrebroekdock which also handle ro/ro and general cargo traffic. However, this picture is about to change drastically in the years to come, following the long-awaited opening of the Deurganckdock on the left bank of the river Scheldt (for the location of the main container terminals in the port of Antwerp, see figure in Appendix).

In a first phase the Deurganckdock, which provides Antwerp with a much-needed extra capacity of about 2.5 million teu in 2006, is expected to attract business that is currently handled on terminals located on the right bank. Indeed, the recent strong growth in container traffic in the port of Antwerp (see Table 1) has put enormous pressure on the right bank terminals, leading to severe congestion problems during peak periods. The Deurganckdock will significantly reduce this pressure and therefore reduce congestion and waiting times in the port of Antwerp. When fully operational (by 2010-2012) the total capacity of the Deurganckdock will amount to 7 million teu. Hence, it will effectively double Antwerp's current container handling capacity and will safeguard its position as a container mainport in the future. On the basis of the expected throughput of 13-14 million

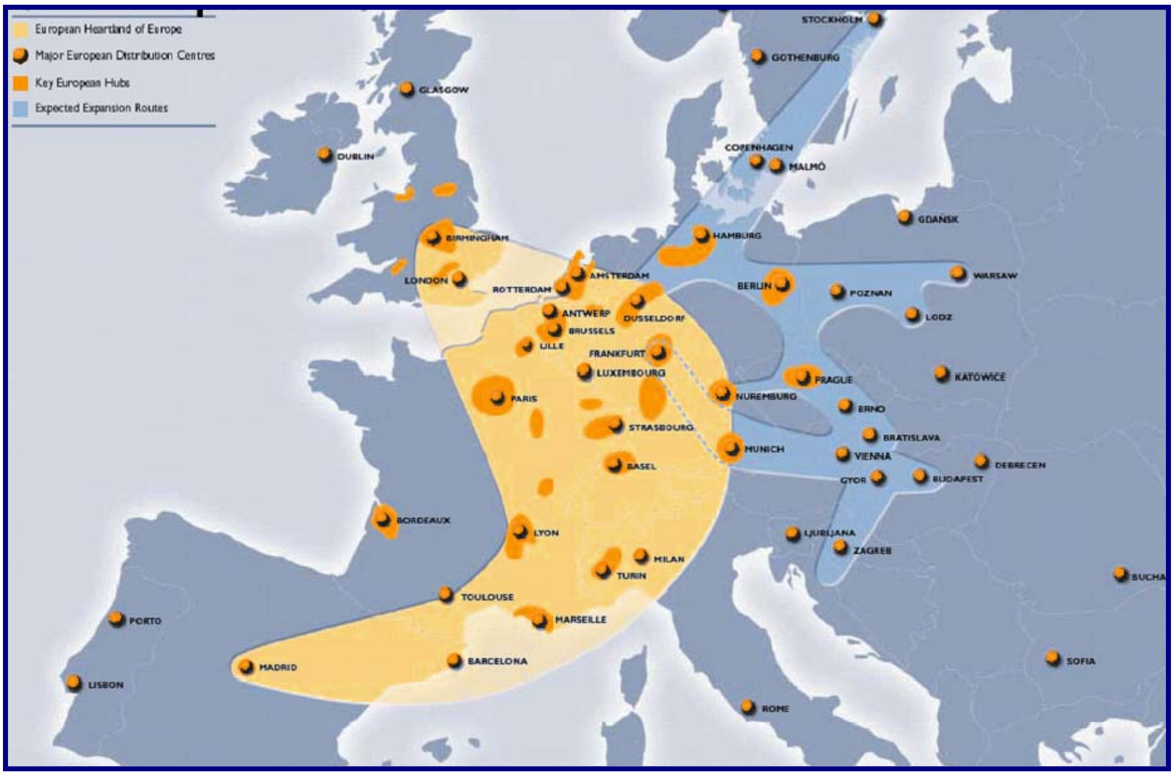
TEU in 2010-2012, the Antwerp Port Authority aims for a modal split of 40% road, 40% barge and 20% rail. In practice, the port community would be rather satisfied if rail would manage to achieve a 15% market share.

## 3. The importance of hinterland networks for container ports

The performance of seaports is strongly entwined with the development and performance of associated networks that give access to cargo bases in the hinterland. Container ports are only as competitive as the inland and relay links that connect to it.

Antwerp, as well as many other ports in the Hamburg-Le Havre range, has a strategic location in relation to the so-called 'blue banana', an area where the main economic centres in Europe are concentrated. In the medium term the traditional 'blue banana' will approach the shape of a boomerang as a result of extensions to central and east Europe and significant investments in the Mediterranean (Spain in particular) (see Figure 2). Northern ports, in particular Hamburg, are likely to benefit the most from EU enlargement, whereas new development opportunities might arise for secondary port systems in the Adriatic and the Baltic Sea. This development has broadened container port competition in Europe. An increasing number of ports gain direct hinterland access to the 'blue banana' area. Antwerp has always competed with other large and medium-sized load centres in the Hamburg-Le Havre range. However, Antwerp's rivals seem no longer to be limited to the handful of load centres in the Hamburg-Le Havre range.

**Figure 2: The 'blue banana' in transition**




Source: Cushman & Wakefield, Healey & Baker

Most mainline operators running deepsea liner services to/from the Hamburg-Le Havre range stick to line bundling itineraries with calls scheduled in each of the main markets, i.e. three to five regional load centres per loop of which one call at a load centre in the UK. Rotterdam, Le Havre and Hamburg are important first ports of call on the routes where post-panamax vessels are deployed. Antwerp and Le Havre are the main last ports of call on the loops of container shipping lines.

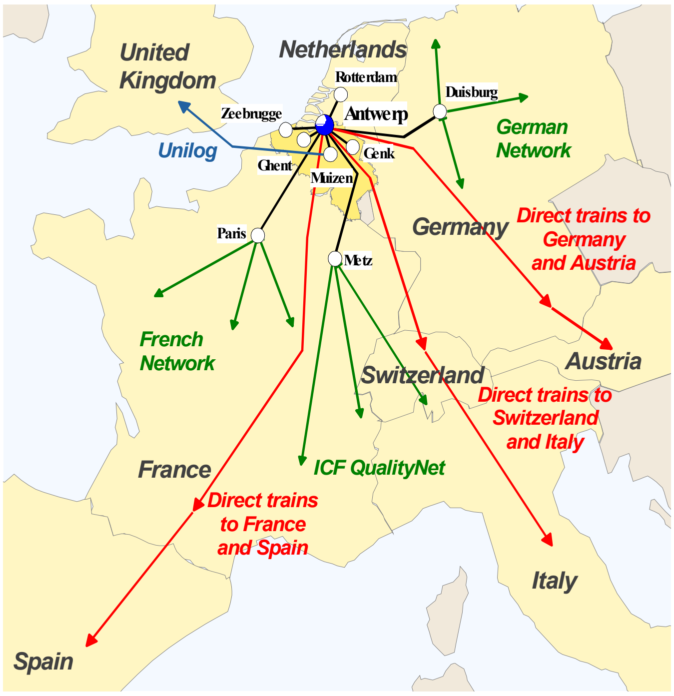
Maritime hub-and-spoke networks and related feeder connections in northern Europe have not developed to the level predicted by some observers. Sea-sea transhipment volumes in the Hamburg-Le Havre range do not exceed 40% of any port's throughput. Consequently, the competitiveness of the load centres in the range is largely determined by the ports' capabilities in dealing with container flows to the immediate and more distant hinterland regions.

The port of Antwerp faces tough competition from other ports in the region, even in relation to service areas in the immediate hinterland. Antwerp competes heavily with Rotterdam for local and European hinterland cargo, with Le Havre for French cargo and with Bremen and Hamburg for traffic to/from Germany, the Alpine region, northern Italy and Central and Eastern Europe. Major hinterland overlap regions characterized by intense port rivalry are the Rhine-axis (the German Ruhr-Area in particular), northern France, northern Italy and the east-west corridors from the Benelux ports to the hinterland. The regions close to the Antwerp port are not captive. In Germany, competition levels for serving certain important hinterland regions are extremely high and one can even observe a clear distribution of local container flows among various ports. The tendency towards intense competition for shared hinterlands is further enhanced by the development of intermodal corridors and inland terminals. By developing strong functional links with particular inland terminals a port might intrude in the natural hinterland of competing ports. 'Islands' in the distant hinterland are created in which the load centre achieves a comparative cost and service advantage vis-à-vis rival seaports (Notteboom and Rodrigue, 2005).

In contrast to other ports in the region, Antwerp has a very high proportion of container flows that is generated by the city of Antwerp and its immediate region. About 28 % of containers handled via Antwerp by truck are to/from markets within a radius of 50 km (figures AGHA/SEA). This is directly related to the port's role as a cargo generating location linked to the strong manufacturing base of the immediate hinterland.

When it comes to container transport by rail, the port of Antwerp offers a blend of hub-based networks, direct shuttles, inter-port shuttles (e.g. DeltaExpress and PortExpress between Antwerp and Rotterdam and Railbarge on the Antwerp-Zeebrugge link) and block trains (see Figure 3). The multimodal hub at the right bank plays a crucial role as bundling point. Rotterdam and Antwerp each have between 150 and 200 intermodal rail departures per week. Le Havre features only a limited number of direct shuttles via the joint venture Le Havre Shuttles (LHS), but is well connected to CNC's hub-and-spoke network assembled around a central node near Paris. Hamburg's rail connections outperform all other ports in numbers (i.e. more than 160 international and national shuttle and block train services per week) and in traffic volumes by rail (i.e. nearly 1 million TEU in 2003). The ongoing rail liberalization process should lead to real pan-European rail services on a one-stop shop basis. All over Europe, new entrants are emerging. Since 2003, Belgian Rail is competing with Dillen & Le Jeune Cargo while SNCF, Railion and rail4chem are in the process of entering the Belgian market in 2006.

**Figure 3: Antwerp's rail network for containerized cargo**




Source: Belgian Rail

Barge container transport in Europe has its origins in transport between Antwerp, Rotterdam and the Rhine basin, and in the last decade it has also developed greatly along the north-south axis between the Benelux and northern France (Notteboom and Konings, 2004). Antwerp and Rotterdam together handle about 95% of total European container transport by barge. Volumes on the Rhine have increased from 200,000 TEU in 1985 to some 1.6 million TEU in 2004 leading to higher frequencies and bigger vessels. At present the liner service networks offered on the Rhine are mainly of the line bundling type with each rotation calling at 3 to 8 terminals per navigation area (Lower Rhine, Middle Rhine, Upper Rhine). The inland vessels used on the Rhine have capacities ranging from 90 to 208 TEU, although some bigger units and push convoys of up to 500 TEU can be spotted occasionally. The average frequencies of barge services out of Rotterdam and Antwerp to the Rhine now amount to at least a daily service. Rotterdam has a strong position on barge traffic from/to the lower Rhine and middle Rhine, whereas Antwerp and Rotterdam are equally strong on the upper Rhine.

The number of terminals in the Rhine basin is steadily increasing. This is the result of new terminal operators arriving on the market (e.g. P&O Ports in Duisburg) and of new terminals appearing along the Rhine and its tributaries (e.g. Aschaffenburg, Krefeld and Mannheim Container Terminal). The growing realization of the potential offered by barge container shipping has led to a wave of investment in new terminals over the past few years, in northern France, the Netherlands and Belgium. The Benelux and northern France now have more than 30 container terminals, about as many as in the Rhine basin. The next step is to establish a network of liner services connecting the various terminals outside the Rhine basin on a line bundling basis.

Antwerp plays and will continue to play a leading role in barge and rail services. A good intra-port transport system is needed to bundle container volumes in the most efficient way as to make the rail and barge option as attractive as possible. A crucial fact in this respect is that about 70% of the hinterland traffic at Deurganckdock will have to cross the river, which makes the bundling of container cargo a challenging task.

As mentioned in the Introduction to this paper, road transport, rail transport and inland navigation have a limited capacity to capture the growing container volumes in the port of Antwerp. Hence, the idea of constructing a dedicated Underground Logistics System (ULS) to transfer containers between both banks of the river Scheldt seems tempting. In the following section a first analysis of different variants of such an ULS is presented.

## 4. An Underground Logistics System (ULS) for the Deurganckdock

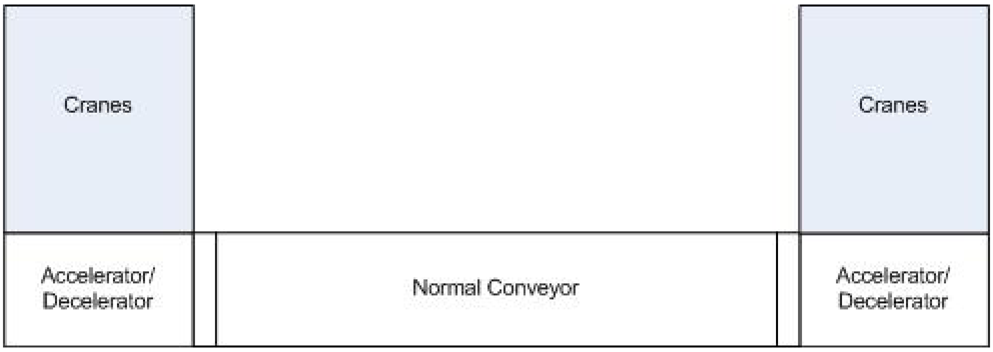
In this section we focus on two different technical solutions for moving containers under the river Scheldt in the port of Antwerp. Both require a tunnel, but use two different means of access: a vertical shaft entry or a ramp entry. The choice of entry greatly determines the further technical possibilities, as will be explained in the following subsections.

### 4.1 An ULS with vertical shaft entry

We will start by looking at the possibilities of a vertical shaft entry towards the tunnel. Vertical movement is necessary to insert and extract containers into/from the tunnel. This part of the system is also responsible for movement between vertical shaft and drop-off point. A horizontal movement is required to transfer the containers from one side of the tunnel to the other.

A single conveyor belt from the beginning to the end of the tunnel seems to be an obvious choice for the horizontal movement of the containers. However, due to the sheer weight of a single container, it is not possible to put a container on a moving conveyor. Doing this would create an enormous and intolerable strain on the individual parts of the conveyor. The conveyor system therefore has to consist of different sections (see Figure 4): a first section accelerates the conveyor onto a second one moving at a constant speed to the other side of the tunnel where a decelerator conveyor slows the container to a standstill. When the container is lowered in the vertical shaft, it will be placed on the accelerator conveyor which is standing still. The accelerator section then moves the container towards the second conveyor whilst accelerating the container to the speed of second conveyor. This process has to be accurately controlled to allow for a smooth transition from first conveyor to second one. The container then travels at a constant speed towards the other end of the tunnel. At the end of the second section the opposite action has to take place: the container moves from the second conveyor to the third which is moving in synchronism, once the transfer is complete the last conveyor starts its deceleration manoeuvre to halt the container from where it can be extracted from the tunnel.

**Figure 4: Side view of a ULS with vertical shaft entry**

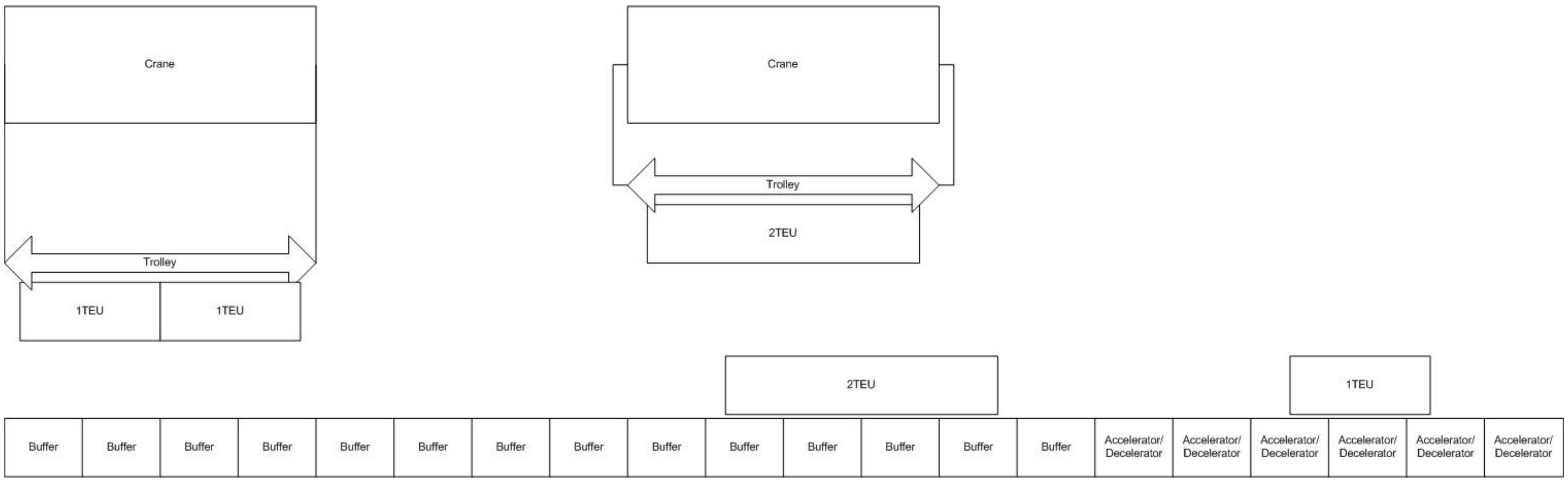



Of course, reliability of the ULS is a great concern. In case of malfunction of one of the conveyors, the entire system would come to a halt. Therefore every section itself consists of multiple subsections which function independently. If these subsections are dimensioned to less than a container's length, a failure of one or more of these will not seriously influence the functioning as long as they are not consecutive. These subsections would be complete drive systems: electrical motor, gear boxes, bearings, conveyor … and could be easily extracted and replaced by a spare one as to reduce repair time to a minimum; only a power cord, control cord and mechanical locking would have to be manually fixed.

The vertical movement could be realized by a gantry crane. Straddle carriers supply the containers, which are lowered by the crane into the vertical shaft. If the gantry is wide enough, there can be a small stock of containers within. It is also possible to engineer a dedicated lift system as well. However, if we want to obtain the desired container transfer capacity, this vertical movement forms the bottleneck. It is not possible to lower the containers at a high enough rate with just a single gantry crane or lift. Therefore more gantries have to be used in parallel: either by placing the gantries side by side, requiring a switch to bring all the containers to the same conveyor or by placing the gantries one after another over the underground conveyor belt and with adequate control, timing and buffer zones containers can be lowered down on the conveyor. The latter system is easier to construct than the underground switch system (see Figure 5).

Simulation shows that the required capacity of container transport from left to right bank and vice versa can only be realized by two tunnels, one for each direction. With this system, both tunnels can transport containers in both directions so that in case of real failure in one of the tunnels a minimal capacity of transport can still be realized in either direction, or in case of temporary non-symmetrical transport demands, a tunnel's transport direction could easily be reversed.

**Figure 5: Side view of buffer with cranes and accelerator/decelerator**



## 4.2 An ULS with ramp entry

If we use a tunnel with ramp entry, we have at least two possibilities for moving containers: we can use either AGV’s (automatic guided vehicles) or rail shuttles for the transport.

### 4.2.1 A system with AGV’s

AGV’s are driverless, computer-controlled transporters. They are programmed to pick up and deliver materials or containers, and provide fully automated transport between two points. They can follow either a fixed or free path, making it possible to extend the AGV system beyond the tunnel. A complete AGV system consists of AGV’s, a guidance system and a controller with software for dispatching, routing and traffic management. The software chooses an AGV for each transport, plans routes and avoids traffic jams.

The interface with the rest of the ULS system may be manual or automatic. Manual transfer can be done with straddle carriers, like loading and unloading a lorry. Transfer can also be done with quay cranes. The crane then takes a container from a ship and lowers the container(s) directly onto the AGV. Automated transfer can be realized with a cassette, this is a support that fits between the container(s) and the AGV. To pick up a container, the AGV lowers itself, goes under the cassette, and lifts up the cassette with the container. This, however adds to the volume and size of the AGV-system and requires more complex AGV’s. There is also the possibility of automatic sideways transfer of a container between an AGV and a train or truck. This is done via a “containerlift”-system, which can be integrated on an AGV. One advantage is that the containerlift AGV can load and unload itself; the disadvantages are the increased the size, weight and complexity of the AGV. Yet another possibility is use of a tractor-AGV. The container is then put onto a road-legal trailer or equivalent and instead of a human-driven tractor an automated vehicle is used to drive the container through the tunnel. This involves changing the trailer from tractor to tractor twice in a short period time. This process would have to be automated to keep handling costs at an acceptable level.

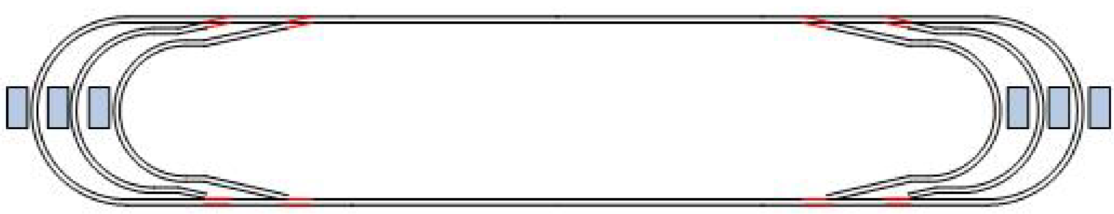
With AGV’s one can create a flexible, optimized system with reliable operation, a large throughput and little space requirements. Layout can easily be altered or expanded. A system with two tunnels would be desirable, but reversing the direction of traffic does not pose any problems. The system could be operational at reduced capacity when the first tunnel is finished.

There are drawbacks, however. AGV’s are very expensive, and the ULS for the Deurganckdock would require a lot of them to move the expected volumes. Because AGV’s must carry their own power supply and because of the high weight of the containers to be moved in and out of the tunnel, batteries are not a workable solution. A diesel engine would be a workable alternative. This requires a costly ventilation system for tunnel or a very costly hybrid drive system in the AGV.

### 4.2.2 A system with rail shuttles

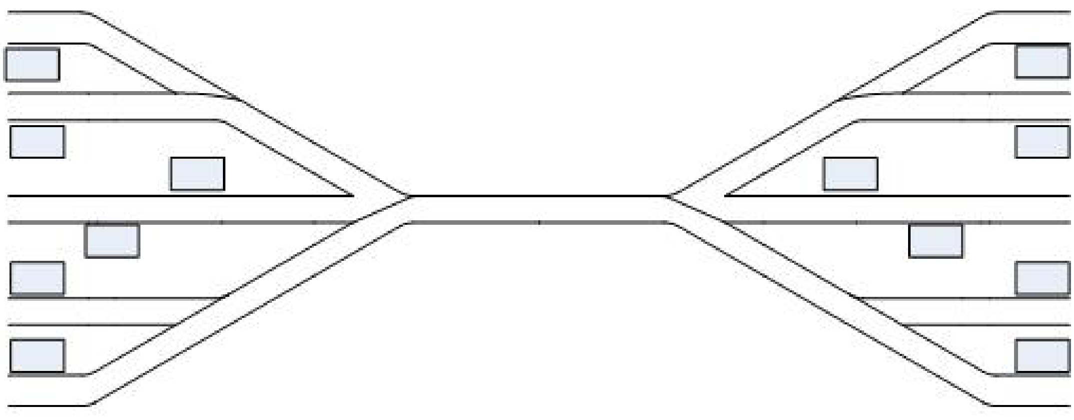
Rail shuttles are dedicated, electrically powered, driverless freight cars. On ground level, the shuttle can be loaded using a gantry crane as well as container forklift trucks. The vehicle then takes off towards the tunnel and descends. During descent, a lot of power is inserted in the main supply. The railcar then proceeds towards the other end of the tunnel at low energy consumption. The ascent of the railcar is marked by a large power consumption. If there is some synchronism however, the power generated by a descending railcar can be used by an ascending one. Still, a large peak power reserve has to be available. Electrical power to the shuttle can be provided through sliding contacts underneath the shuttle instead of the classic overhead contact wire which would be hampering the vertical loading and unloading procedure.

**Figure 6: Above view of circular layout**



In order to fluently load and unload the shuttles, several loading and unloading docks have to be implemented (See figure 6). This means that straddle carriers or forklift trucks need to cross the shuttle tracks to reach some parts of the loading/unloading area when considering circle lines. For safety reasons it might be better to use a star-layout (see Figure 7).

**Figure 7: Above view of star layout**



The shuttles can drive in both directions. In case of a blocked tunnel, transportation is still possible at a diminished transfer capacity using only one shaft.

A rail shuttle can operate in a tube with a smaller diameter than a tube for AGV's because of the smaller wheels and the absence of fuel tanks or batteries. Therefore the tunnel for a rail shuttle can be constructed at a lower cost. The rail shuttle system uses only proven technology, which results in greater reliability. However, the drawbacks cannot be ignored. Making a U-turn in a circular lay-out with a railcar of about 20 m in length is not evident in a limited space, so a lot more space is required than with other solutions. Rolling stock is very expensive and it is likely that the total cost will be relatively high. Flexibility is limited: changing the layout would require extensive and expensive rework of the rail system.

## 5. Conclusions

The opening of the Deurganckdock, located on the left bank in the port of Antwerp, has increased the port's container handling capacity by several millions of teu per annum, which should enable it to cope with the expected volume increases over the years to come. However, estimates by the Antwerp Port Authority indicate that about 70% of containers to be handled at the Deurganckdock (transhipment containers excluded) have a hinterland origin/destination which necessitates a crossing of the river Scheldt. Because the capacity of the traditional transportation modes (road, rail and barge) for linking both river banks is limited, the construction of a dedicated Underground Logistics System (ULS) for the Deurganckdock seems tempting. This paper presents a first analysis of different variants of such an ULS. Although the conveyor based system clearly offers a number of advantages, a detailed modelling of all variants is necessary to allow for a detailed cost and throughput analysis.

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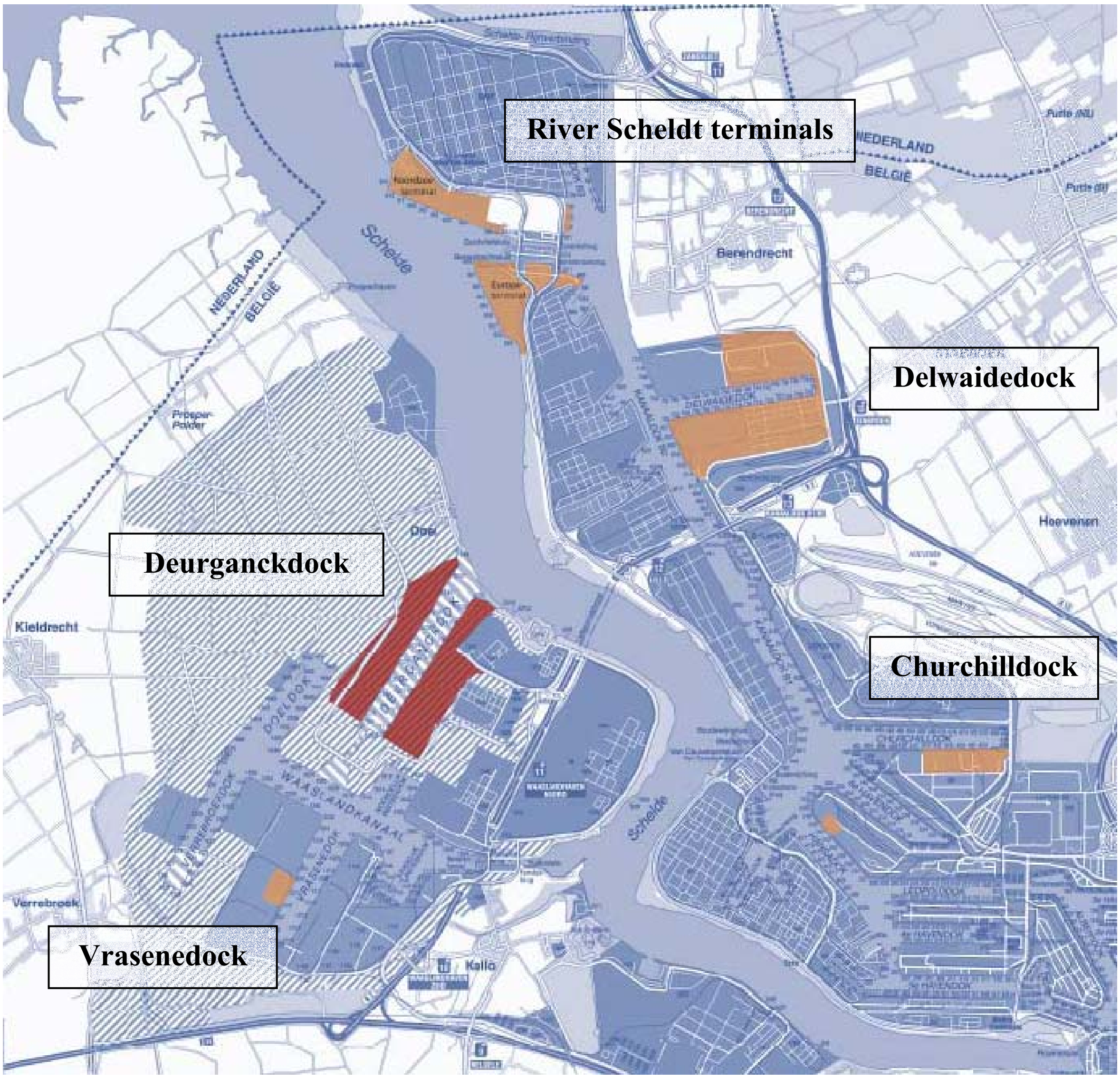
# Appendix: Main container terminals in the Port of Antwerp




Source: Antwerp Port Authority (2005), Port of Antwerp: World Scale Container Port in the Heart of Europe, Antwerp, 20 pp.