Identification of promising Twin Hub networks

Report of Work Package 1 of the Intermodal rail freight Twin hub Network Northwest Europe - project

Final report

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NETWORK
TWIN HUB
INTERMODAL RAIL FREIGHT TWIN HUB NETWORK NORTH WEST EUROPE

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Contents

Terms and abbreviations

Load unit	Any box used in intermodal rail transport, such as containers, swap bodies and semi-trailers. ISO containers are used in maritime transport, containers suitable for euro-pallets in continental transport, swap bodies in continental transport and semi-trailers in continental transport (including short-sea).
TEU	Transport Equivalent Unit = 20’ ISO container.
TEU factor	The ratio of number of containers and the number of TEUs they represent. The TEU factor in the maritime sector has grown from 1,5 to currently about 1,7, due to the market penetration of larger containers such as the 45’ container.

Part A Overview and background of the Twin hub network project

1 Introduction

(E. Kreutzberger and R. Konings)

1.1 INTERREG Northwest Europe (NWE)

This report is the first deliverable of the project ***Intermodal Rail Freight Twin Hub Network Northwest Europe***. We call its subject ***Twin hub network*** and the organisational entity to carry out the actions the ***Twin hub project***. The project is funded by INTERREG NWE (programme IVb). Its work started in December 2011 and will end by the end of 2015. The project budget was, when the project started, about **5,7 million Euros**, to be spent in **4 years'** time. The project consists of analytical and designing actions and of the project pilot. The latter is the centre of the project. It is to prove to which extent the theoretical concept can work in practice. Most of the project budget is earmarked for the actions within or related to the pilot.[1]

1.2 Red thread through the project's content

The red thread through the project's content is described by the following bullets.

1.2.1 Problems

The starting notion is that the share of intermodal rail transport should increase, for societal and commercial reasons. Societal because – on many transport relations – the external costs of transport are lower for rail than of road (Vaghi et al., 2002; IFEU and SGKV, 2002). Commercial because intermodal rail transport is, given the expected growth rates, a spearhead or large opportunity of the rail sector. Europe-wide the current share of intermodal transport in rail freight transport is estimated at 15% (Becker, 2014). However, forecasts indicate that the intermodal transport volume could triple by 2030 and achieve a share of 50% in total rail freight traffic (Hämel, 2013).

In large transport nodes, like large seaports, there is an additional societal motive for aiming at large shares of (intermodal) rail (and barge) transport, namely limited space and limited infrastructure capacity in the ports. As the space requirement of infrastructure per ton-km of transport is smaller for rail (and barge) than for road transport, seaports as Rotterdam have ambitious modal shift ambitions. The long-term ambition of the port authority Rotterdam is to realize a modal shift, for rail from 11% to 20%, for barge from 40% to 45% and for truck from 47% to 35% in 2035 (Port Authority Rotterdam, 2008). Considering that the port authority Rotterdam expects a substantial growth of container throughput this modal shift will be even more challenging. In the concession contracts of new container terminal operators at Maasvlakte 2 the operators must meet the criterion that at least 65% of their hinterland transport is carried out in an intermodal way (barge and rail).

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1 This was about 3,5 million euros when the project started. Later, when the project decided which regions the pilot network would serve, when therefore the distances of pilot trains became clear, and when the project's budget – in the framework of a Request for changes submitted to INTERREG, the project's budget was reduced to 2,1 million euros, reduction totally referring to the pilot.

The growth aims are challenging. In most areas the real growth is significantly smaller then desired and intermodal shares remain modest (Savy, 2007; Becker, 2014). The gap is largely caused by poor intermodal performances. Intermodal quality still is poor in terms of network connectivity and service frequency. Exceptions are some large flow corridors,[2] from and to some large nodes, and in some well-organized regions (Cardebring *et al.*, 2000; CER, 2013). Quality refers terms as transport reliability, transport time, service frequency, network connectivity and logistic match, the latter describing the appropriateness of the response of the transport to the customer system. Logistic match refers to the locations of rail terminals and locations of shippers, or to time synchronisation like whether the departure and arrival times of trains fit well to the requirements or preferences of shippers.

Rail transport is chosen for its low costs (Gruppo CLAS *et al.*, 1998; NEA *et al.*, 2002). But frequently the door-to-door rail costs are considered to be too high, while – at least a part of – the sector has difficulties to cover the costs of its operations (many examples in Kreutzberger and Konings, 2013a). The smaller market of high value goods is interested in a better quality, but largely not willing to pay higher prices for a better rail quality (RUPS and NEA, 2003).

In network parts with very large flows it is difficult to accommodate the traffic. The projected increase of the share of rail from 11% to 20% in Rotterdam implies that rail freight doubles, triples or more (Keyrail, 2008). The crisis has tempered the growth, but what remains still is substantial.

Both, the problem of lacking growth and shares, and the problem with facilitating large flows, call for transport innovation. Its quality, costs or cost-quality-ratio need to be improved.

1.2.2 Innovation challenges

Core challenges of rail freight innovation are:

1) increasing the scale of transport, in other words the size of trainloads or – equivalently – improving the service frequency or rail network connectivity;
2) increasing the roundtrip productivity (speed) of trains;
3) improving the door-to-door time of load units;
4) introducing train concepts which cope with the lack of track capacity;
5) improving the handling at begin- and end terminals or at intermediate exchange nodes;
6) improving the pre- and post-haulage;
7) improving the spatial organisation of rail and customer systems and improving other items of the logistic match between transport providers and transport customers;
8) improving the technical, intelligence or communication to support innovation measures responding to the above-mentioned innovation challenges.

These challenges are classical ones for the railway sector (and of other transport sectors). Twin hub is a concept facing the same challenges, but solving them innovatively. It primarily responds to challenge 1 (transport scale), but also responds to challenges 2, 3 and 4.

[2] The most important example of a large flow corridor in Europe and intermodal rail transport providing a good quality is the BLUE banana segment between the Northsea and northern Italy.

1.2.3 A innovation response: the Twin hub concept

The central idea of Twin hub network is to bundle the flows of different seaports in the range Duinkerke (northern France) – Amsterdam, in particular of the seaports Antwerp and Rotterdam. The bundling serves to increase the size of trainloads, access more inland terminals, increase the service frequency and improve track utilisation.
The flow bundling is to take place by means of hub-and-spoke networks. The Twin hub network consists of numerous hub-and-spoke networks. In each of them a small number of trains departs from different seaports or different rail terminals of a seaport, meet at a hub to exchange load units, and move on to different inland terminals v.v. The hubs are located in the gravity regions of the flows. In the initial concept this was the region Antwerp and Rotterdam. Eventually a third hub location was added, namely Dourges near Lille. The concept includes some operational principles to enhance the efficiency of the networks. One of them is that each train and load unit only visits one hub per journey, either Rotterdam, or Antwerp or Dourges.

The planning and implementation of the concept is to be possible for the entire intermodal rail market including SME rail operators. For most SMEs the planning and operation of a hub-and-spoke network is too large of an event to do on your own. The network must be organised and run by several operators. They then need to cooperate. So Twin hub operations may be based on the cooperation of competing rail operators. They cooperate in order to improve their performances. Cooperation between competitors also takes place between seaports. The hub-and-spoke networks are to integrate the flows of different seaports, also if they belong to different countries. All of this cooperation is innovative.

The concept and the used specialist terms are explained in Chapter 3, after first having presented the basics of freight bundling (Chapter 2).

1.3 The project structure

The work in the Twin hub project is organised in four work packages (WPs) (see figure 1.1):

- WP 1 (*market analysis and network design*) has the task to identify promising Twin hub hub-and-spoke networks for the pilot. It is also to develop the means to identify promising Twin hub hub-and-spoke networks for the long term, and to discuss the cost implications of alternative hub locations. The work is organised in two actions, namely (Action 1) mapping the flows and (Action 2) different steps to identify **promising connections** for hub-and-spoke networks. This work constitutes the fundament for all actions within the Twin hub project.

- WP 2: (*pilot-train services and information system*): The network concept is to be tested in practice in a pilot. The pilot (WP 2) is the centre of the Twin hub project and absorbs most of the project's budget. The pilot operations are to be monitored. The rail operators in the project on the basis of the results of WP 1 choose connections to test in a **pilot hub-and-spoke network**, and they choose the hub to use. The choice and its motivation is part of the **Pilot business plan** (Action 3) which addresses all issues needed to be clarified to let the pilot to become a

success. Each train connection in the pilot is an action. The project intends to have three train connections in the pilot (Actions 4, 5 and 6). The rail operators take all preparations such as organising the resources (traction, wagons etc.), train paths and terminal slots. The pilot lasts half a year. Such period is considered to be sufficient to see whether the (services in the) pilot network are viable. If yes the pilot services move towards their commercial phase, otherwise they must be stopped. A lack of cost-coverage may be due to a lack of revenue in the initial phase and a need to develop routines for cooperating with other firms in the pilot and for needing to use infrastructure that is not developed and completely suitable for hub-and-spoke operations.
Should the pilot revenues not cover their costs in the initial phase, the project's budget allows to compensate 50% of the losses with a maximum of about 350.000 euro per rail operator. This potential subsidy represents state aid and has – on an individual basis – been approved by the European Commission.

The performances of the pilot train services are to be monitored. Making a simple **monitoring system** and monitoring the pilot services is the subject of Action 7. One of the functions of the monitoring system is to evaluate the degree of cost-coverage of the pilot services.

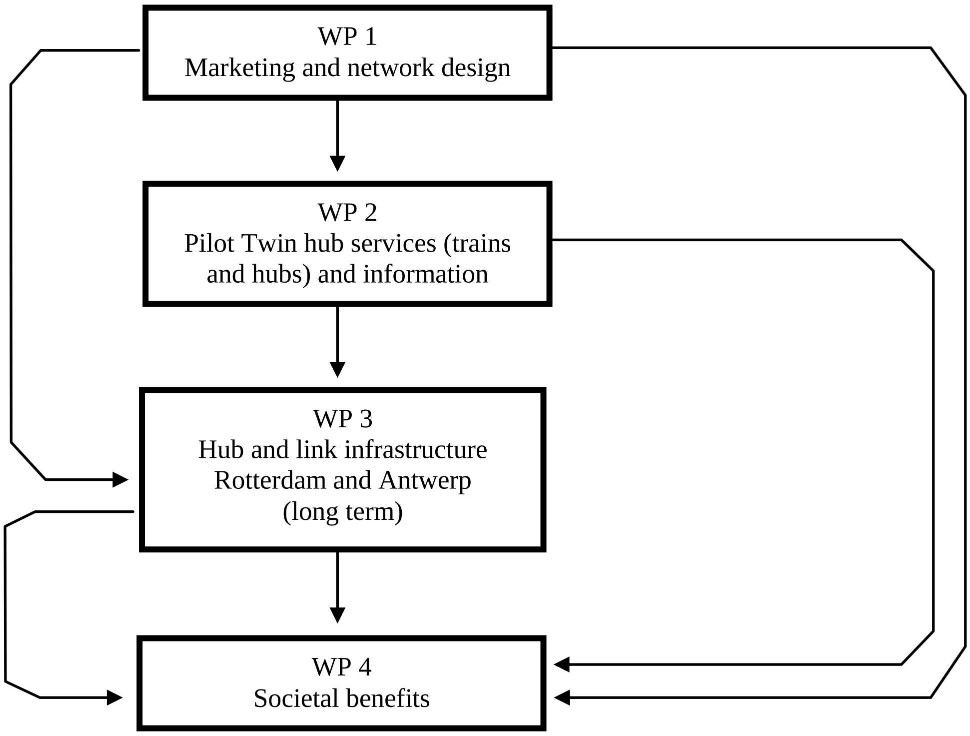
The Twin hub train services are organised by different firms. Their cooperation is likely to benefit from integrating means, like a **joint booking system** which matches the trainloads and train capacity for all pilot connections and is suitable to be adapted or connected to the booking systems of other firms should they eventually participate in the Twin hub network. Developing such a system or at least giving an outline of the structure, characteristics and conditions of such a system is the subject of Action 8. The success of the pilot will not depend on the presence of an all elaborated innovative booking system.

- WP 3 (*hub and link infrastructure Rotterdam and Antwerp*) addresses rail infrastructure, contrary to WP 1 and 2 which are about rail services. Its objective is firstly to clarify which **rail infrastructure** is **required** to make the Twin hub network, when – on the **long term** – it has evolved to a network of substantial scale, ultimately successful. Its second objective is to interest key decision-makers in the field of infrastructure planning and programming for such infrastructure, wherever the infrastructure does not already have advocates. The WP focuses on the hub regions, namely Antwerp and Rotterdam, and not on the infrastructure of the entire network in other European regions. This focus is due to the spatial concentration of rail activities in the hub regions. As for all hub-and-spoke networks, the performance of infrastructure in the hub region is likely to have a strong effect on the train performances throughout the entire network. It should therefore perform well.

  The main rail infrastructure elements in the hub regions are the hub and the tracks from and to the hub. Antwerp had the Mainhub terminal, which was truly developed for rail-rail transhipment (Gemels and Buyse, 2013), but recently has been closed because of the shut-down of its main customer, a domestic hub-and-spoke network. The question is how to organise rail hub exchange in the future and whether the reopening of the Mainhub for international hub-and-spoke networks is an option. Rotterdam has no hub terminal, but only rail-road terminals and shunting yards. Very few of these nodes are useful for rail-rail exchange the short term, but eventually a hub terminal needs to be built. This WP presents a systematic overview of hub terminal options, including the best location at the East side of the port and – if relevant – including the tracks from and to the hub. The overviews are used in roundtable conferences with key decision-makers in the field of infrastructure development.

- WP 4 (*societal benefits*): this work package analyses the societal benefits for different stakeholders, in particular the 1) intermodal rail sector, 2) the regions (large ports, small ports, inland terminals and their regions), 3) European policies (territorial and economic cohesion; technology and employment and the strategy of Lisboa; sustainability and the strategy of Gothenburg), 4) the total. The multi-criteria-multi-actor analysis will confirm to which extent the Twin hub concept satisfies the project's and INTERREG's aims and objectives.

Figure 1.1 The structure of work packages in the Twin hub project



1.4 The partners in the project

The challenges in the Twin hub project have a transnational nature. The composition of the project partnership reflects this fact. The transnationally cooperating **partners** in the Twin hub project are:

- The **rail operators** Russell (UK), IMS Belgium (B) and ERS (NL);
- The **port authorities** Rotterdam and Zeeland;
- The **universities** Delft, Rotterdam, Brussels, Karlsruhe;
- The **consultants** NEA, Nieuwenhuis Rail Expertise and Ab-Ovo.

The Delft University of Technology coordinates the project. The most important features of the management are described in Appendix 1.

2 The bundling challenge

(E. Kreutzberger)

2.1 Overview

Increasing the scale of transport is one of the central challenges (no. 1 above) to make intermodal rail transport more competitive. The challenge consists of organising large trainloads also for flows, which are too small to fill a direct train on the required frequency level. Bundling is the magic word in this context. One can organise large trainloads for small(er) flows by:

- ***Categorical bundling***. Different freight categories like intermodal flows and non-intermodal flows are bundled to trainloads;
- ***Temporal bundling***, meaning that the service frequency is reduced;
- ***Directional bundling***. The flows of different rail connections are bundled. We call this ***complex bundling***;
- ***Network concentration***. There are less terminals in the service areas in change for longer pre-and-post-haulage distances, the latter most often by truck. The so-called ***extended gateway networks*** (e.g. of ECT) belong to this network type;
- Connecting different train services at their begin-and-end terminals, the latter then often called gateway terminals and the connected networks ***gateway networks*** (e.g. of HUPAC; not to be mixed up with the extended gateway networks mentioned before; see Section 2.3.6).

Categorical bundling to some extent almost always takes place, like moving refer containers, chemical containers and general cargo containers, or maritime and continental load units on the same train. **Directional bundling is the most widespread way of organising large trainloads and the centre of the Twin hub project.** Network concentration implies high pre-and-post-haulage costs in normal transport landscapes and therefore is mostly applied in specific transport landscapes where such disadvantages are relative small, like between a large seaport and a central inland terminal in a high-density production and consumption area. Gateway networks hardly generate transport scale, but are easy to organise, as they can be carried out only using the own terminals of an intermodal rail operator. For such reason they have become popular, in particular for new players in the market.

2.2 The principle of complex bundling

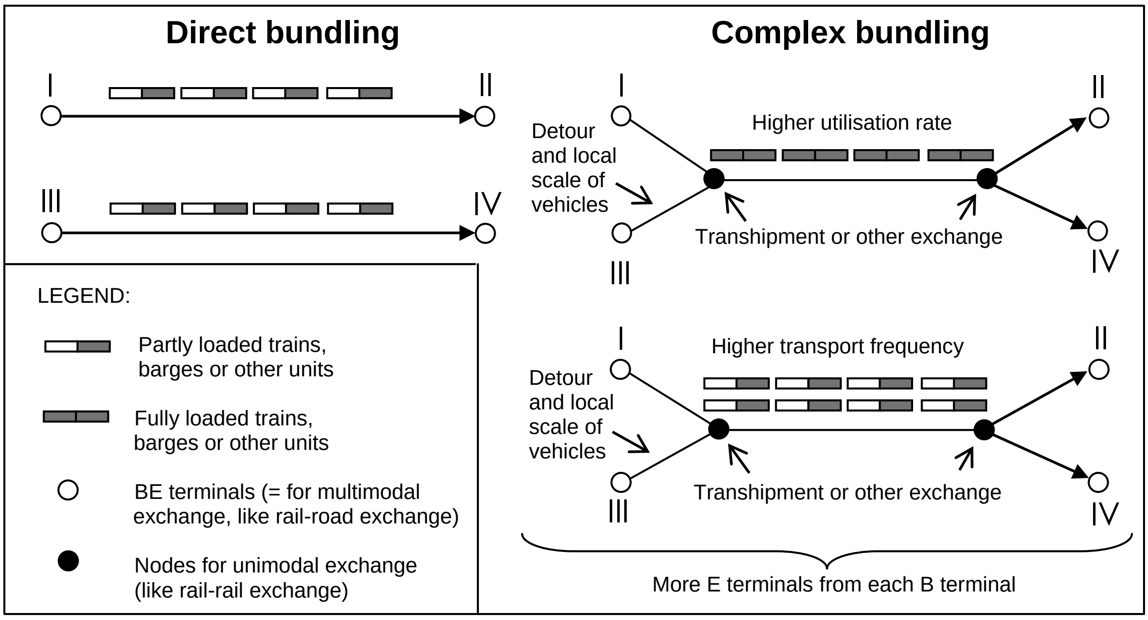
The principle of complex bundling is visualised in Figure 2.1. On the left side it shows two train connections, one from A to B, the other from C to D. Both trains are half loaded. If instead of moving these flows separately all the way, the flows are bundled to a trainload during part of their journey (right side of Figure 2.1):

a) the size of the trainload can be increased (upper picture);
b) the service frequency can be increased (lower picture);
c) a combination of larger trainloads and higher service frequencies can be achieved;
d) the network connectivity can be increased as the complex bundling network accesses more end terminals from each begin terminal;

e) (in case of larger trainloads) the track infrastructure is used more efficiently as each train path services more load units.

Effect (a) reduces the fixed train costs per load unit, effect (b) the time costs of the owner of goods and the storage costs, effect (d) potentially the pre- and post-haulage costs and effect (e) the infrastructure costs per load unit-km.

Figure 2.1 The principle and impacts of bundling*



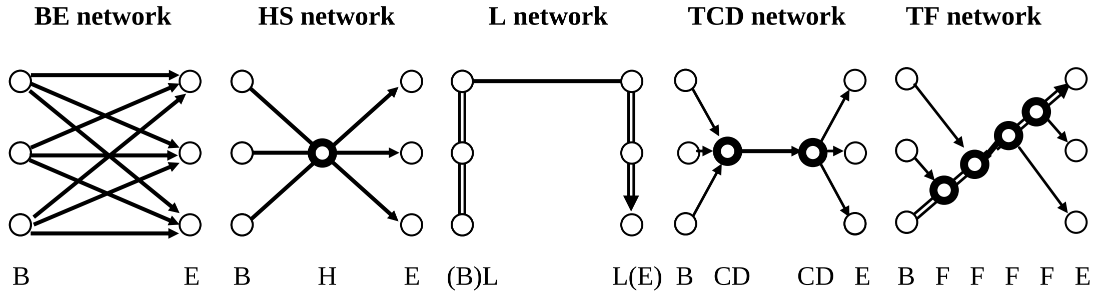
* The figure only shows the main transport mode (e.g. rail) and no pre- and post haulage.
** Source: e.g. Kreutzberger 2008.

Of course complex bundling also implies a number of disadvantages and the challenge is to minimise these. The disadvantages are (Figure 2.1) that the routes are longer (= presence of a detour factor), there might be additional exchange at intermediate exchange nodes and there might be local network parts with relative small trainloads, hence expensive network parts.

We distinguish five basic types of bundling flows (Figure 2.2), namely direct networks and the complex bundling networks: hub-and-poke networks (= HS networks), line networks, fork networks and trunk-feeder networks. Direct and HS networks only consist of trunk network parts, hence only have trunk (= relative large) trainloads. The direct and the line network are the only ones in which a load unit only has two transhipments, between rail and road. The other three network types[3] also have local network parts in which the trainloads are smaller increasing the average train costs per load unit-km, and more than one intermediate exchange node.

3 In case we are dealing with so-called directed network versions, in which the exchanging trains have a certain direction (like from left to right). The all-directional network is its opposite incorporating both directions (back and forth) for exchange. The difference is very visible for hub-and-spoke networks.

Figure 2.2 The basic bundling types*



LEGEND
= trunk train service (BE network and HS network)
or trunk part of a trunk train service (L network and TF network)
= local part of a trunk train service (L network and TF network)
= local train service (TCD network and TF network)
= BE terminal (in L network also L terminal)
= intermediate unimodal (e.g. rail-rail) exchange node

BE network = begin-and-end network (or direct network)
HS network = hub-and-spoke network
L network = line network
TCD network = trunk-collection-and-distribution network (or fork network)
TF network = trunk-feeder network

B = begin terminal E = end terminal H = hub node L = line terminal
CD = collection-and-distribution node F = feeder node

*
The figure does not show pre-and-post-haulage.

Train networks are "uni-directional and separated" ones.

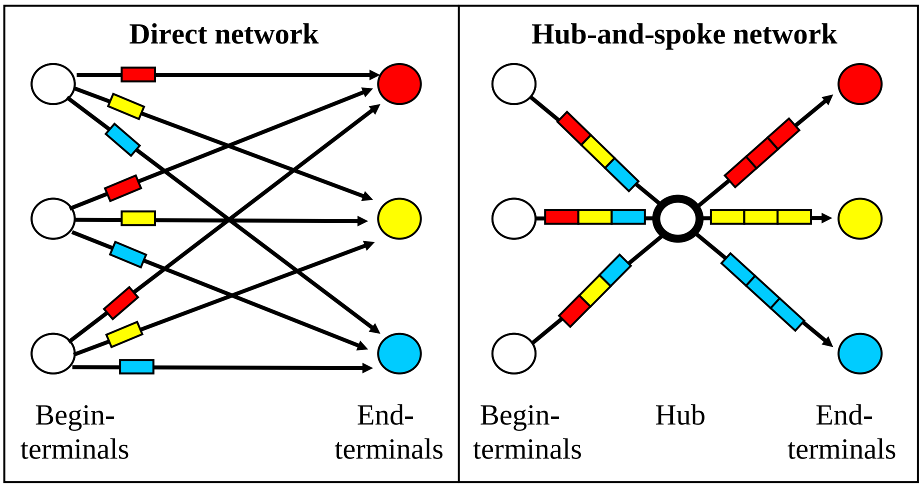
Source: Kreutzberger, 2008.

The most relevant difference between all bundling alternatives is the number of train connections through the network. The direct network has the most (in the example of Figure 2.2 nine connections), the HS network a medium number (in the example of Figure 2.2 three connections). The other three networks in their trunk part all have one connection. This difference of number of connections is the fundament for providing economies of scale or scope also for small(er) flows and transport nodes. In general, if there are enough flows to fill the nine direct trains on the desired frequency level, the direct service network is the best solution. Otherwise the HS or other complex bundling networks may be the best solution.
Explained for HS network, the – in comparison to the direct network – smaller number of connections (Figure 2.3) allows to either increase the size of the trainloads (upper picture of Figure 2.3) or the frequency level (middle picture). Alternatively, the HS network can, given a same size of trainloads and service frequencies, respond to smaller flow sizes (lower picture) than the direct network can.

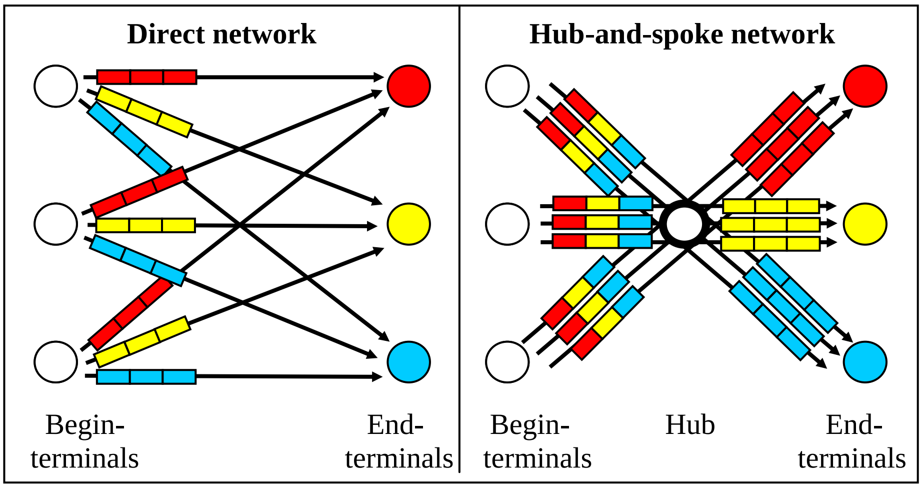
Which bundling type is the most appropriate, depends on the size of flows involved, the expectations towards the transport services, the ambitions of the transport sector, and on the geographical structure of a region or node. Which bundling type is applied, also depends on the policies of involved companies. In different seaports we observe different complex bundling types, due to several of the mentioned reasons. **Rotterdam** for its intermodal hinterland rail connections mainly applies line bundling, **Antwerp** HS bundling, **Hamburg** and **Bremen** have a mix of bundling types. In all cases, there is a need for complex bundling, because from and to large

Figure 2.3 The potential advantages of HS bundling in comparison to direct networks

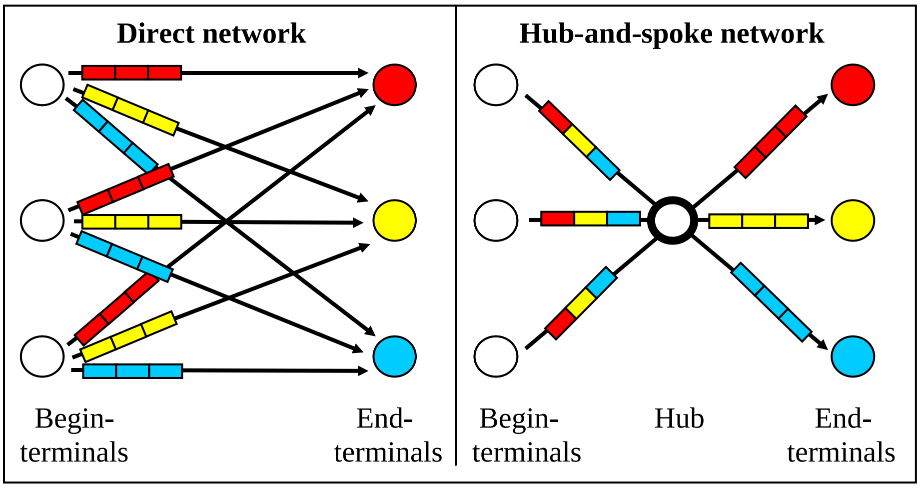
HS network: larger trainloads than in the direct network



HS network: higher transport frequencies than in the direct network



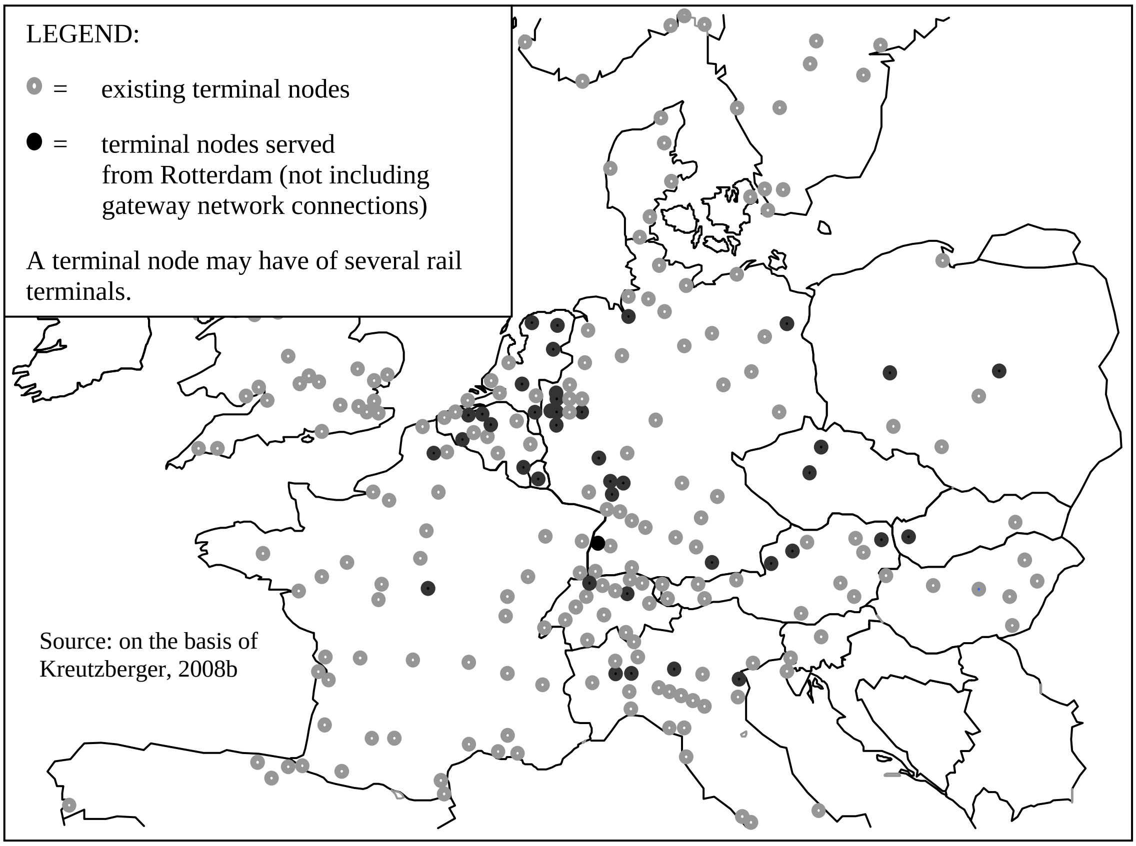
HS network: smaller transport network volumes required than in the direct network



Source: Kreutzberger, 2011

transport nodes like large seaports there are many small(er) flows next to the large ones. Not serving the small(er) ones sufficiently contributes to the picture in Figure 2.4: only some of the intermodal rail inland terminals in Europe (the black ones) are connected to Rotterdam by trains. Even in the "own" hinterland of Rotterdam, the southeast corridor from the seaport, many terminals remain non-accessed. Why? Often because the combination of flows being too small for direct train services and of too many actors focusing on direct bundling.

Figure 2.4 Intermodal rail terminals served from Rotterdam in 2005 (in black)



Complex bundling networks also have an incubation function. While freight flows are growing, very small unimodal road flows become suitable for complex bundling rail services, and medium-sized flows in complex bundling rail networks become suitable for direct train services. If flows on a transport relation or of a rail operator are not large enough for direct transport services, the actors can either leave them to the road sector or organise services in complex bundling networks. Complex rail services with full trainloads may be less profitable than direct ones with full trainloads, but nevertheless can be profitable or at least cost-covering. Nodes or operators that take the effort to organise complex bundling rail services will improve their position in the future market of direct trains services. Concluding, complex rail networks are the incubator of direct rail services.

2.3 The physical means of complex bundling

2.3.1 Exchange types

Next to the functional features addressed above bundling also has a physical dimension. This is about the means and types of operations used to exchange load units at nodes and about the types of trains involved. Generally, rail-rail exchange between trains can take place in several ways (see e.g. Kreutzberger and Konings, 2013b):

a) exchanging single wagons between trains (along with their load units) by means of shunting;
b) exchanging wagon groups between trains (along with their load units) by means of shunting. Most often each wagon group represents a certain direction;
c) transhipping load units at a terminal;
d) exchanging load units by roll-on or roll-off (RoRo) systems. The involved load units then are semi-trailers or trucks.

Exchanging single wagons between trains (operation type a) requires a gravity shunting yard, is relatively costly (on the basis of Symonds, 2001) and certainly is very time consuming (Franke and Vogtman, 1999). It hardly is an option for efficient intermodal rail operations and certainly not for the Twin hub concept.

Exchanging wagon groups between trains (b) takes, if restricted to a small number of wagon groups, place at a flat shunting yard. This type of operation generates competitive exchange costs (on the basis of Gaidzik *et al.*, 1994) and is relatively fast (study of timetables of DB Cargo, 1999). But it is only suitable for the wagon group market. In other words, the involved flows need to be large enough to fill wagon groups. This type of operation was, still in the 1990s, the backbone of the European complex bundling in intermodal rail transport (KombiConsult and K+P, 2007).

Transhipping load units at a terminal (c) leads to competitive exchange costs and times and is suitable for all intermodal markets (not only for the wagon group market).
RoRo systems are, as restricted to semi-trailers etc., outside of the scope of most intermodal rail networks including the Twin hub network.

Concluding, the operational types (a) and (d) are no option for most intermodal rail hub-and-spoke networks including the Twin hub network, (c) is the best solution and (d) is a good solution in numerous situations.

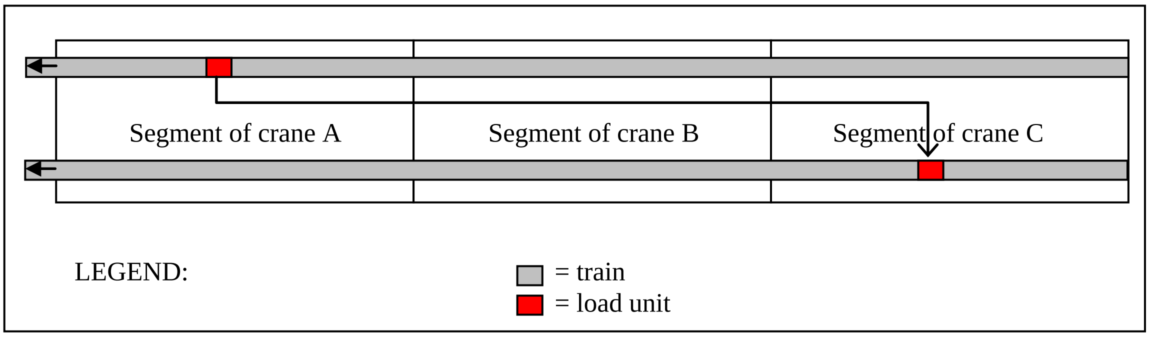
Focussing on hub-and-spoke networks, the ones with only terminal transhipment, also at the hub, can employ ***block trains*** or ***shuttles***. The first have a fixed train length and wagon composition during an entire journey, the shuttles during a sequence of journeys. Networks with shunting hubs employ ***wagon group trains*** and ***single wagon trains***. These change their train length and wagon composition at the hub. ***Complete trains*** are wagon group or single wagon trains with (intentionally) full trainloads during an entire journey.
Twin hub network can be based on block trains, shuttles, and (complete) wagon group trains.

2.3.2 True hub terminals

True hub terminals have different characteristics distinguishing them from than begin-and-end terminals (see also Kreutzberger and Konings, 2013c). To accomplish large amounts of rail-rail transhipment efficiently, they have a different layout including more tracks beneath a train, optionally less distance between the tracks, the presence of a terminal internal transport and sorting system. Also their locations differ. A true hub terminal is located near the rail entry of a seaport (or other large transport node). Its location also makes it easy for trains to reach all train corridors of that node, like – for Rotterdam – the Randstad tracks, the Betuweroute, the Brabantroute and the southern tracks.

The challenge for the terminal internal transport and sorting system is to move containers from – to mention an extreme – the front position of one train to the back position of another train (Figure 2.5), without asking much crane capacity. The internal transport and sorting system can consist of simple to high performance systems like respectively a simple truck lane or high-tech robotised pallet system.

Figure 2.5 Changing crane segments for rail-rail exchange at a hub terminal



The degree to which a terminal internal transport and sorting system is required, depends on the amount of sorting activities at the begin terminal. If there was appropriate sorting of load units at the begin-terminals, the or most of the load units changing trains at the hub would arrive in the right crane segment of the hub. In this case the crane work could remain limited even if there was no internal transport and sorting system. If – the contrary – trains are loaded randomly at the begin terminal, sorting and relatively much internal transport is required at the hub terminal.

The Mainhub Antwerp was the pioneer in the implementation of true hub terminals. After the Mainhub a very small number of other true hub terminals has been implemented in Europe.[4] End of 2013 the Mainhub was shut down, after the Belgian government announcing to stop the subsidy to its main user, the Belgian domestic rail container network NARCON. Awaiting a new business plan for the Mainhub, the regions Antwerp and Rotterdam do not dispose of any true hub terminal.

For the pilot this is no problem, as the small amounts of rail-rail exchange can take place at existing nodes, including rail-road terminals, at least if they have sufficient capacity reserves. The potential nodes are presented and discussed in Section 6.4.

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4 See WP 3 report.

2.4 Conclusions

Wherever the size of flows is sufficient to fill trains on the required frequency level, direct bundling is the best solution. But if the size of flows is smaller, other configurations, in particular complex bundling networks, must be organised. Hub-and-spoke bundling is very promising in this regard, as it is based on trunk network trains (with intentionally full trainloads). Short local trains are absent.

At the hub there are – in terms of exchange costs and time – two acceptable types of operations, namely transhipment of load units at terminals and exchange of wagon groups (with load units) at flat shunting yards. Terminal transhipment in principle is better, because it is suitable for all intermodal rail markets, not only the wagon group market.

Small amounts of rail-rail transhipment, as present in the Twin hub pilot network, can be carried out at a rail-road terminal. If the rail-rail transhipment takes place simultaneously, which is advisable for hub-and-spoke networks with rather low service frequencies, the terminal must have sufficient capacity reserves to facilitate the time requirements of the hub-and-spoke trains.

If the majority of rail-rail exchanges serves rail services with critical time windows, a high performance hub terminal may be beneficial. These do not exist at all yet.

3 The Twin hub network

(E. Kreutzberger)

3.1 The Twin hub network

Twin hub network is about bundling the flows from Antwerp and Rotterdam and of smaller seaports in the range Duinkerke - Duinkerke including Zeebrugge, Vlissingen, Moerdijk and Amsterdam. Such bundling allows to:

- increase the size of the trainloads;
- then also increase the utilisation of tracks, as each train path is used by more load units;
- increase the service frequency;
- increase the network connectivity, meaning that more inland terminals and seaports can be accessed by rail including smaller ones;
- provide rail services also for smaller flows.

The central device for the bundling is: Let Dutch load units lift along in Antwerp trains wherever these have or could have a strong market position. And let Belgian load units lift along with Rotterdam trains wherever these have or could have a strong market position. Smaller seaports preferably get attached to the train services of the two large ones. Inland terminals move their load units in joint trains to the seaports instead of separate ones to each seaport.

The bundling is to take place by means of hub-and-spoke networks. In fact, Twin hub network is a title for a larger set of HS networks. Each of them consists of 2 to 6 (or maybe more) trains, which meet at the hub to mutually exchange load units. Ideally most of the exchange is a simultaneous or direct one, meaning that the exchanging trains are present at the hub during the same period and that there is no interference of the stack.[5] In the ideal operation trains of an exchange batch (= HS network) depart from different seaports and/or from different rail terminals of a seaport, visit the hub during the same period in order to exchange load units and then pass on to different hinterland terminals v.v. (Figure 3.1). Up to the hub trains have load units to several inland terminals. After the exchange each train is single destiny loaded meaning that it carries load units only to one inland terminal.[6]

The Twin hub network has two hubs, located in the gravity points of the involved flows, namely the regions Antwerp and Rotterdam (Figure 3.1). Each train and load unit only visits one hub during its journey. Which hub will be used largely depends on the geographical orientation of the envisaged HS network. If a larger part of its spokes is heading to the southwest, the HS network will probably have its hub in Antwerp. If it is heading more to the northeast, Rotterdam is likely to serve as the network's hub. Some of the Twin hub HS networks are centred on the hub Rotterdam, others on the

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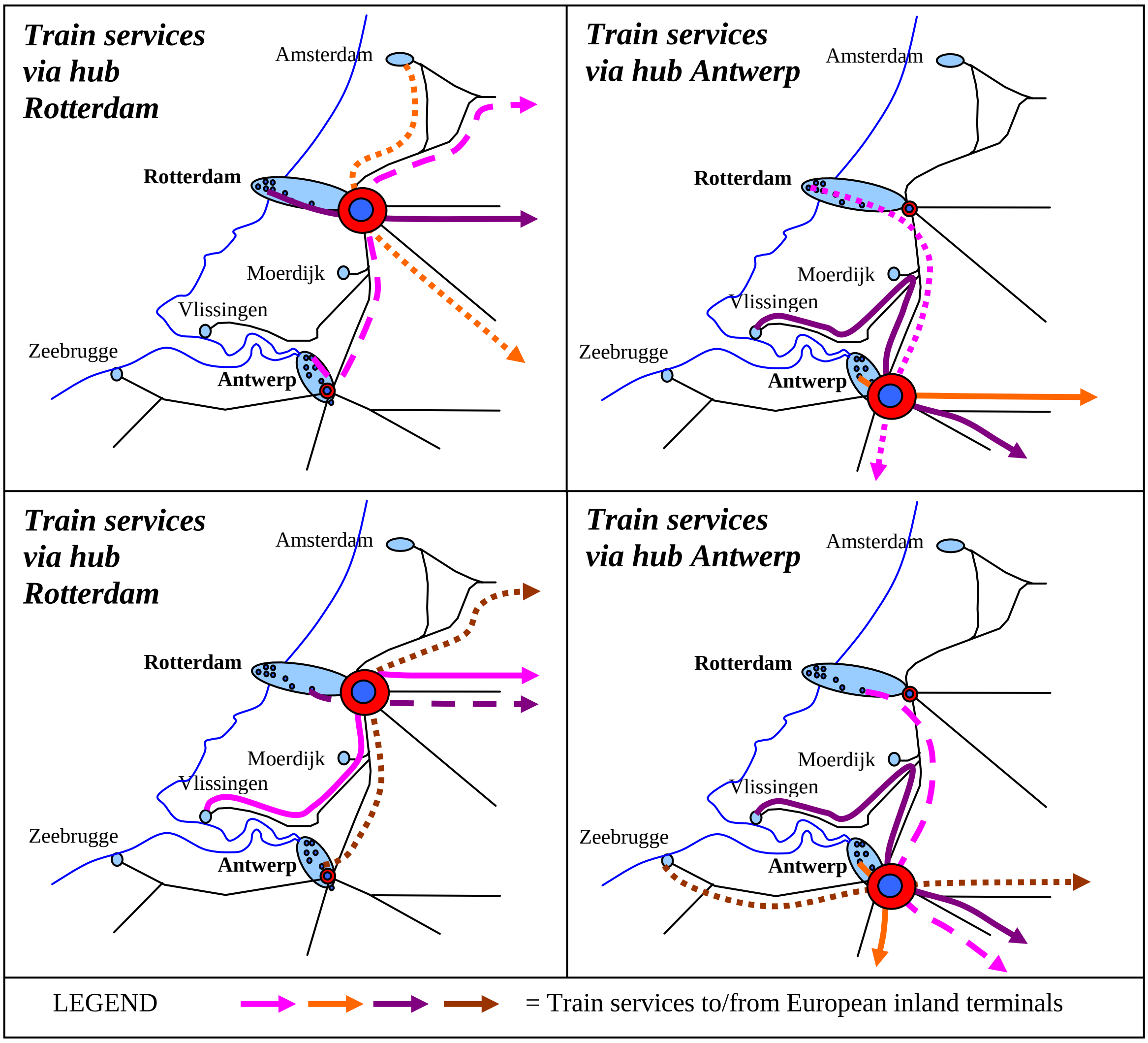
5 The load units may be set on the ground for a short period, but this is more or less next to the train and not in the stack area.

6 Or to two (or more) if the train stops at two (or more) inland terminals, applying line, fork or trunk-feeder bundling (see Figure 2.2) at the inland end of a spoke.

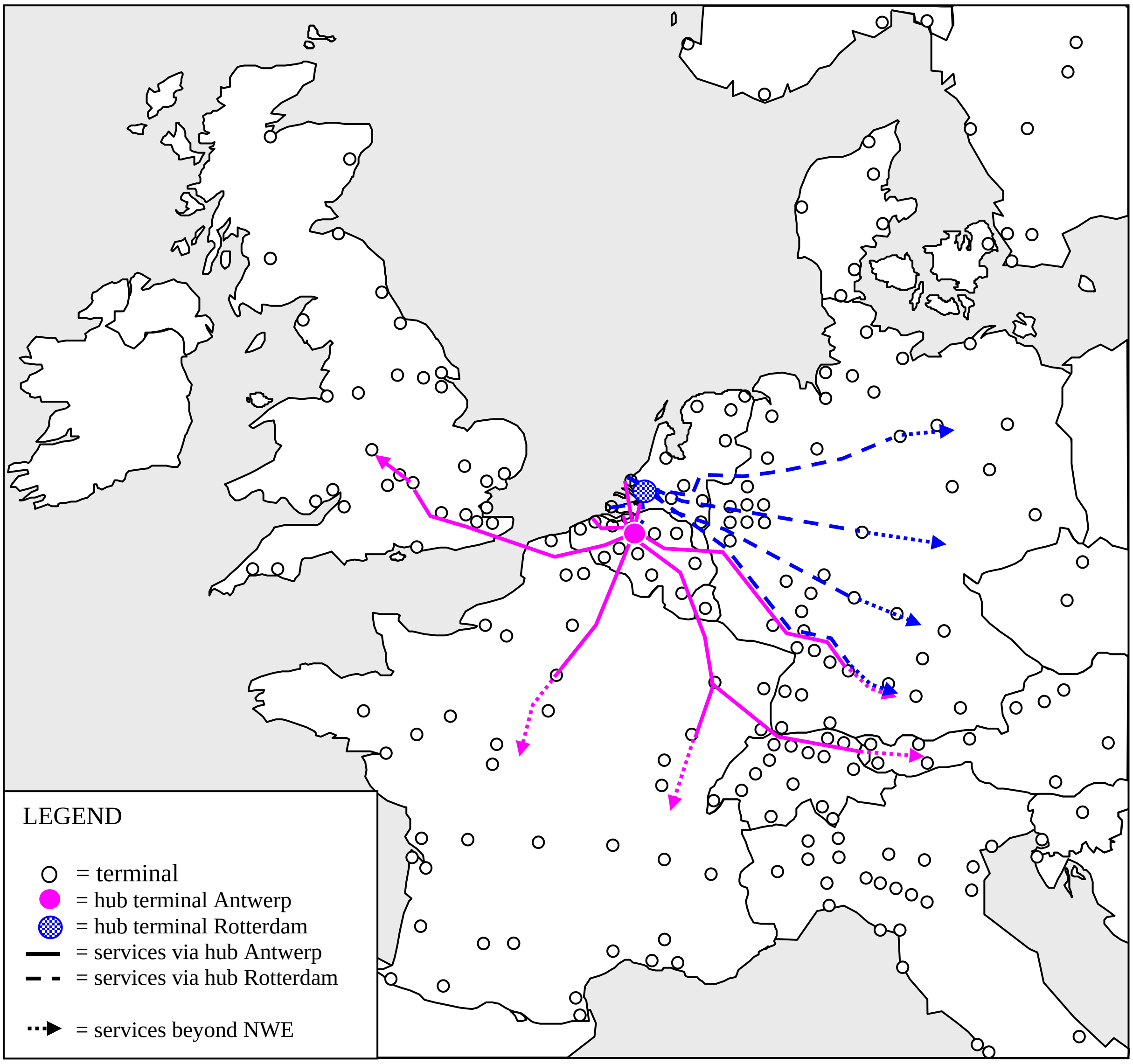
Figure 3.1 Examples of hub-and spoke networks within the Twin hub network



hub Antwerp. Which node within the region will be used as a hub, depends on its suitability and availability. Figure 3.2 shows two HS networks being part of the Twin hub network, one centred on Antwerp, the other on Rotterdam. The train services access Northwest Europe and also go beyond this area.

The concept implies that the service area of the hub Rotterdam is not restricted to the port of Rotterdam and the service area of Antwerp not to the port of Antwerp. Instead the service areas of each hub overlap. The hub Rotterdam also accesses terminals in Belgium and the hub Antwerp also terminals in the Netherlands. The extension of the service areas allows improving the performances (larger trainloads, higher frequencies and network connectivity) more than if each seaport only bundles its own flows. The overlap of service areas of the hubs is one of the central features distinguishing Twin hub networks from ordinary HS networks.
However, in acknowledgement of seaport competition the cooperation of Antwerp and Rotterdam in such a concept is likely to be a complementary one, meaning that both hubs serve complementary hinterland corridors. Trains (networks) running via the hub Rotterdam will often run in the eastern and north-eastern direction, trains (networks) via Antwerp in the southern to south-western direction.

Figure 3.2 Impression of two hub-and-spoke networks being part of the Twin hub network



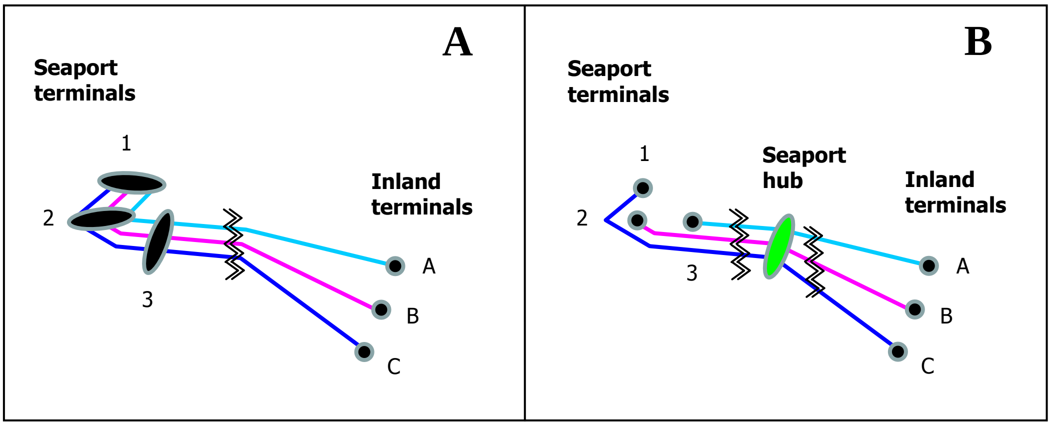
The choice of micro-location for the hub (which terminal or other node to use as the hub in the regions Rotterdam and Antwerp?) depends on its suitability and availability. The main aspects of suitability are "type of node" (rail-rail terminal, rail-road terminal, flat shunting yard, gravity shunting yard) and location. Ideally the hub is located near the splitting point of tracks to different corridors.

3.2 Contribution to better logistics in the seaport

The Twin hub concept assumes that each large seaport (Antwerp and Rotterdam) already or eventually has its own rail hub, and that the rail hub has a location which is suitable to bundle all intermodal rail flows of that seaport and of smaller seaports in its surrounding. The ideal location of the rail hub is near an entry of the rail network to the seaport, and at a point from where all corridors of the seaport can easily be accessed. Easily means, without large detours and without complicated additional operations.

Rotterdam does not have a hub terminal, due to its tradition of line bundling for trainloads which do not fill a train (Section 2.2). The flows of the increasing number of rail terminals in the seaport, however, are difficult to bundle by line services. Hub-and-spoke is a promising rail alternative. Letting a train visit a seaport hub implies additional handling and time costs, on the other hand contributes to the above mentioned benefits of complex bundling and allows to save time at the seaport terminals. Train practices of IMS in the seaport of Rotterdam illustrate what is at stake. Some of their trains currently visit more than one terminal on the Maasvlakte (as in Figure 3.3 A). The number of visited terminals can be minimised without reducing network connectivity by transhipping load units at a seaport (Figure 3.3 B). The outlines of benefits can be drawn knowing that dwell times of a train at a maritime rail terminal are very long (e.g. 12 hours) due to the priority of deep sea handling above landside handling.

Figure 3.3 Trade-off between visiting several seaport terminals (A) or a hub (B)



Antwerp until recently had a terminal with the described location characteristics and being designed as a true hub terminal (Section 2.3.2). It has been closed end of 2013 (Section 2.3.2) bringing Antwerp into a position comparable with Rotterdam. In Antwerp however, barge plays a relative important role for collecting and distributing containers between the rail terminals and between shippers and the rail system.

3.3 Operational principles

The described bundling of flows is to take place in a way avoiding any non-productive type of operation:

- no trains with small trainloads. *Advantage: low train costs per load unit.* Hub-and-spoke bundling responds positively to such idea (Section 2.2). Hub-and-spoke bundling only employs trunk trains which intentionally have large trainloads;
- trains and load units during a journey only visit one hub. *Advantage: less node costs and dwell time;*

- trains exchanging load units at the hub ideally visit the hub simultaneously, especially if service frequencies are low (like 3 services per week and direction). *Advantage: a limited demand for storage demand at the terminal AND shorter door-to-door transport times for load units;*
- trains belonging to a certain exchange batch, have similar roundtrip characteristics (e.g. day-A/B or day-A/C services). *Advantage: this makes it easier to organise hub exchange and certainly simultaneous hub exchange.* Flows moved on trains with different roundtrip characteristics might better switch trains, which sequentially visit the hub;
- no shunting of single wagons. *Advantage: relative low costs and short exchange times (Section 2.3.1);*
- preferably the rail-rail exchange takes place by terminal transhipment. *Advantage: acceptable exchange costs and times for all intermodal rail markets, not only for the flows which are large enough for the wagon group market (Section 2.3.1);*
- no diesel traction anywhere, if possible. *Advantage: cheaper and more less external costs (climate, pollution; noise);*
- in case the hub is a terminal, no switch to terminal locomotives, if possible. To avoid such switch, the trunk (electric) train should move in to the (non-electrified) terminal by momentum or backwards. *Advantage: a large part of the technical controls can be avoided. Therefore shorter dwell times of trains and load units at the terminal and lower train costs.* Alternatively the trains are pulled by a hybrid locomotive (electric traction for the network, diesel for the nodes) or the terminals dispose over specific equipment (like switchable electric power lines).

3.3 Transnational and other cooperation

3.3.1 Transnational

Working transnationally is hardly a choice in transport and transport research. Most non-local transport services are transnational ones, certainly those in which rail plays a role, and certainly those, which begin or end in small countries like the Netherlands or Belgium. The initiators of transnational services must cope with the conditions and circumstances of several countries, in the field of traction (different rail electricity), wagons (different gauges), train paths and terminal slots (different national or local procedures or attitudes), social conditions (e.g. labour costs and working regulations) or geographical features (e.g. large difference of terminal density). Successfully organising intermodal door-to-door transport depends on appropriately responding to all of these differences. This is the minimal level of required transnational cooperation, also present in the Twin hub network.

3.3.2 Cooperation of competitors

The Twin hub network has transnational features, which go beyond that minimum and beyond that of many transport networks and services, namely:

a) cooperation between competing intermodal rail operators. This cooperation is likely to be a transnational cooperation;
b) the cooperation between competing seaports. The seaports are ("bundling Antwerp and Rotterdam flows") located in different countries, the cooperation of the competing seaports therefore is a transnational one.

These features, if present on a larger scale, are innovative. Existing HS networks are almost always organised within a rail family, like DB Schenker and its intermodal subsidiaries, or SNCF fret and its intermodal subsidiaries, and not across the borders of such a family. Also, existing HS networks typically are restricted to the seaports of only one country, for instance bundling of Germany, France, the Netherlands or Belgium.[7]

The concept of cooperation of competitors fits, as far as the intermodal rail operators are concerned, well to the European policies of liberalising the railway sector.
The liberalisation has led to the market entry of a larger number of new firms operating trains, commercialising train capacity and/or providing traction. Most of them are small to medium-sized enterprises (SMEs). They have a limited research and development power and therefore a different innovation perspective than the national incumbent railway companies and their freight daughters, especially the companies of large countries like Germany, France and Italy. These national companies have rather large research and development departments and hardly depend on external research. Their need for projects like Twin hub network is much smaller than of SMEs. The Twin hub network project therefore focuses on the SMEs or on the operators of smaller countries. This is no aim of the project, but rather a result of partner acquisition.

The cooperation of competing SMEs is very relevant because without such cooperation the size of the firms can hardly develop complex networks like hub-and-spoke networks. The alternative then is to restrict their business to direct and gateway networks. The large operators can develop and exploit hub-and-spoke networks within their firm. The SMEs, to develop and operate hub-and-spoke networks, will often need to cooperate, each (or some) spoke(s) being operated by different firms. So far the functional logic. In practice one will hardly find such cooperation, despite of their benefits (following section). Therefore the Twin hub project has the aim to stimulate cooperation of competitors in hub-and-spoke networks.

3.3.3 The benefits of the transnational cooperation

The benefits of the transnational cooperation are

- the above mentioned ones of bundling the flows (larger trainloads, better infrastructure utilisation, higher frequency, higher network connectivity, ability to respond to smaller transport network flow sizes, incubation function);
- the derived improved regional accessibility as more regions are connected by more than only road transport;
- the derived sustainability improvements due to modal shift due to more competitive intermodal transport;
- the derived decrease of regional disparities, as also smaller seaports and inland nodes can be served;

[7] There are minor exceptions to the national orientation. One is the Rotterdam spoke in the NARCON network (up to 2013; Section 2.3.4). Another exception - at first sight - was the Conliner network (od Stinnes Intermodal), bundling intermodal rail flows of Antwerp and Rotterdam to German rail terminals v.v. (between 2002 and 2006). Here however, TCD bundling (Figure 2.2) rather than hub-and-spoke bundling was applied implying relative small trainloads between Antwerp and Rotterdam.

- the territorial and social-economic coherence due to the higher network rail connectivity.

As far as the more systematic HS network development is associated with erecting a network of true hub terminals, in particular high performance ones, Europe will also be dealing with technology development, very likely supporting an increase of employment in transport and information equipment, soft- and orgware development. The derived benefits respond to the strategies of Lisboa and Gothenburg.

Part B Identifying promising Twin hub train connections for the pilot network

4 Working steps in WP 1

(E. Kreutzberger and R. Konings)

The first work package of the project is devoted to identifying promising Twin hub regions (Action 1) en designing corresponding Twin hub networks (Action 2). This activity:

- focuses on the short term providing **input for the project pilot**: Which regions should the pilot network connect, given the flow structure and the conclusions of the feasibility analysis? The research results are combined with the opinions of (the commercial departments of) the intermodal rail operators participating in the pilot. The operators take the final decision on the content of the pilot network;
- gives an outline of the **potential Twin hub network**. Designing Twin hub networks for all (relevant) flows in Europe is a complex issue, impossible to carry out by hand. Therefore the project has developed a tool, the bundling tool, in order to identify sets of HS rail service networks and other transport services (like direct train services, direct truck services and to-hub and from-hub services). The tool and its results are the subject of Chapter 8.

The working approach to identify a promising pilot Twin hub network consisted of seven steps (Figure 4.1).

Step 1

First the regions in Europe were identified which could be accessed:

- if road containers went by train instead of truck;
- in case the road flows of Antwerp and Rotterdam and potentially other nodes/regions were bundled;
- given certain trainload thresholds (Chapter 5);
- given the initial service frequency agreed on in the project: for the involved distances (day A/B- to day A/C-connections) three services per week on each connection is seen as a level of service which will be accepted by the (potential) rail market.

In correspondence with directional logic the eastbound UK flows were combined with eastbound seaport flows, the westbound with the westbound ones. Dependent on the scenario the eastbound bundling could consist of only Antwerp and Rotterdam flows or also of different groups of UK flows. The flows from smaller seaports were included in the Antwerp or Rotterdam flows (see Chapter 5).

Step 2

Step 2 was the initial network design. It consisted of:

- choosing which of the promising regions are to be connected by the Twin hub pilot network;
- choosing the hub and terminals per region to be used;
- provisionally designing the rail connections, and their operational characteristics (e.g. roundtrip design, number of train sets required).

The central actors in the choice of connections were the involved intermodal rail operators. They, aware of the promising regions (mapping results) and of concrete market opportunities, decided on pilot connections. Partly some latent firm plans were activated which in the daily environment were infeasible, but in the Twin hub framework became a realistic option.

The choice of hub to use, the following part in the initial network design, depended on the geographical orientation of the network and on the suitability and availability of concrete nodes. For the sake of the pilot it is not strictly necessary to use a node specifically developed for intermodal rail-rail exchange. Any node in the regions Antwerp and Rotterdam or sufficiently near to them on the rail corridors to and from these two seaports was envisaged; any node where rail-rail exchange could take place including rail-road terminals and shunting yards.
TUD-OTB investigated the suitability and availability of potential hub nodes (terminals and shunting yards in Rotterdam, Antwerp, Kijfhoek, Moerdijk and Valburg). The rail operators used this information to choose the pilot hub.

For the choice of begin-and-end-terminals within promising regions several approaches were applied. One was the Euro terminal modal (VUB) which compares rail door-to-door costs with the costs of reference chains (e.g. unimodal road), plotting regions for which rail chains are competitive. Using the mapped flows for promising regions its main contribution for the project was to identify the begin-and-end terminal in a promising region with minimal pre- and post-haulage costs.
In additional hand calculations the effect of weighing pre- and post-haulage costs by the size of involved flows was tested.
The rail operators in knowledge of these results and of market opportunities and – sometimes – having preferences because of alliances, chose the begin-and-end terminals for their connection.

The third part of the initial network design was to decide on the operational characteristics of train services: which roundtrip times? Will a train or locomotive serve two spokes, one spoke or only part of a spoke? How many train sets are required, given the service frequency, the distance to be covered and the number of nodes to be visited?

This as most network design activities for the pilot was an iterative process between the rail operators and the other partners in the project. The rail operators carrying the commercial risk of pilot operations had the decisive position in the discussion. The non-operator partners in the project responded to the ideas of the operators by – in bilateral and project-wide meetings – discussing whether the services and network responded well to the Twin hub network concept.

Step 3
In step 3 the flows of the envisaged connections were assigned to different train routes. In this rather technical step there was nothing to choose or optimise, as each route is unique.[8] The flows on all network parts were maximal ones, representing the volumes if all road containers would shift to the road sector. In reality this will not be the case. Which fraction really may be expected in the tracks is analysed in the modal shift analysis (step 6).

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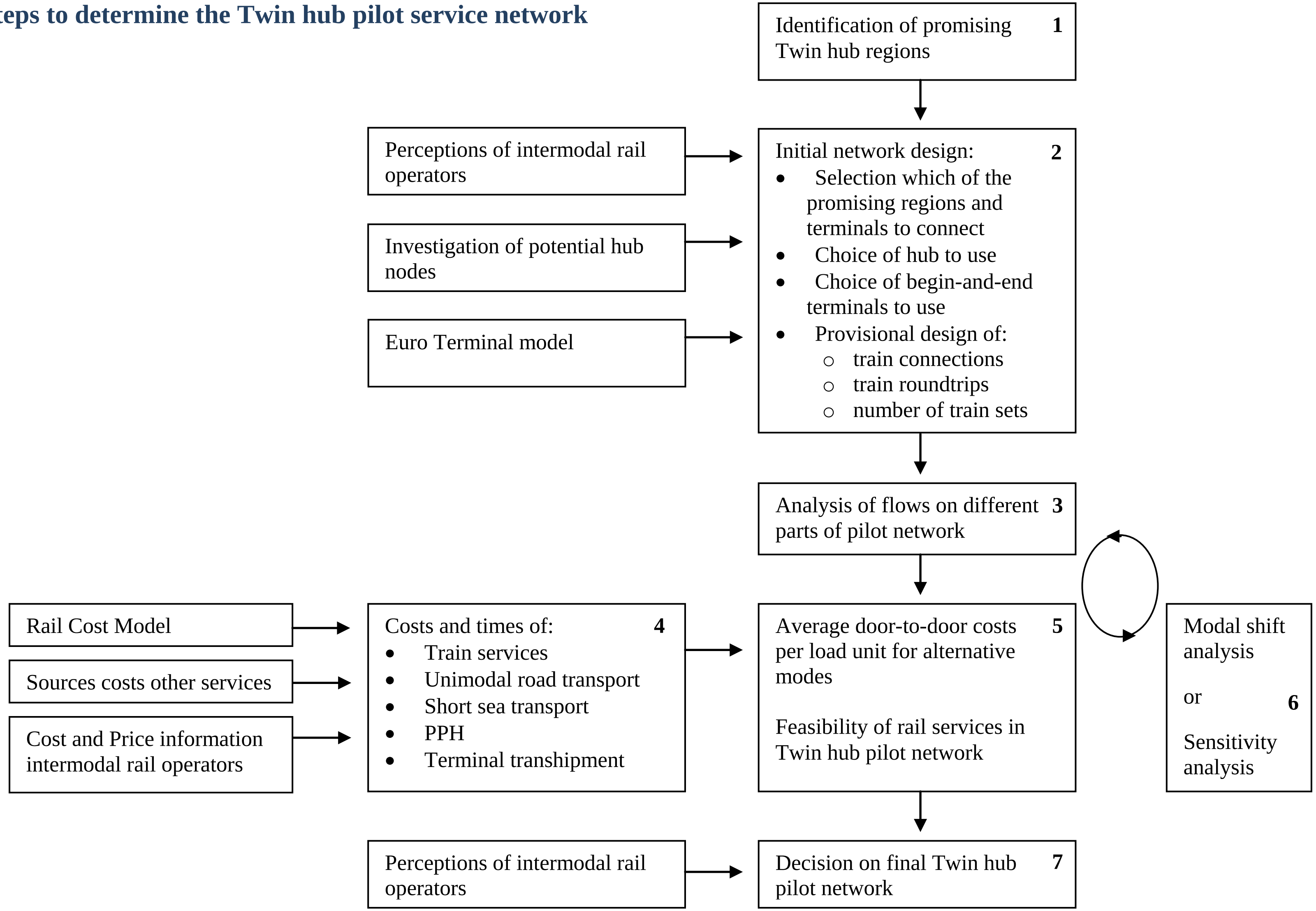
8 Comparable to spanning tree network design.

Figure 4.1 Steps to determine the Twin hub pilot service network



Step 4
Knowing the operations and train equipment needed on each spoke of the pilot network (from step 2), the costs of trains, pre- and post-haulage (PPH), terminal transhipment etc. were calculated or collected for each spoke, and the costs of truck or short-sea services for the corresponding routes (step 4). The calculated costs of train services, unimodal road transport services and PPH services were compared with price information received by operators in the project or other operators or found in published literature.

Step 5
Then, taking account of the size of trainloads (result of step 3), the costs per load unit could be determined (step 5). The involved flows were maximal ones, namely the potential road container flows, the train costs per load units then being relative low. Calculating costs on the basis of potential flows is not realistic. But even under such best circumstances some rail connections are not feasible (like London-Antwerp or London-Rotterdam, as the reference short-sea chains are cheaper). Dismissing the corresponding flows (in the given example dismissing the London-Antwerp and London-Rotterdam flows) reduces the size of trainloads on different connections, implying higher train costs per load unit (again step 5).
Hereafter the feasibility of rail services was tested by means of a sensitivity analysis, anticipating on the possible results of the modal shift analysis to be carried out: how large are the train costs per load unit, if 100%, 50%, 30% or only 20% of the potential flows choose for rail? The results of the sensitivity analysis were fed back to flow level (step 3) in order to recalculate the size of trainloads and average door-to-door costs per load unit and associated feasibility of train services (step 5).

Step 6
In an all-or-nothing approach the rail connections leading to lower intermodal door-to-door costs than unimodal road costs will be chosen by all road containers. In reality such is not the case, but only a part of the road containers will switch to rail transport. Potential reasons are incomplete information, non-rational behaviour, or that rail transport does not sufficiently meet all requirements of some potential customers, like a higher service frequencies, a higher reliability or more suitable departure and arrival times, just to mention some possibilities.

The modal shift analysis (TUD-CITG) is to tackle such decision making appropriately (step 6). Its result is the number of road containers for which rail transport is cheaper and that decide to go by rail. This is only a fraction of the total number of road containers or of what we above called the potential market. The modal shift analysis in WP1 reduces the number of road containers that will choose rail, starting from the total number of road containers per door-to-door connection.
The results of the modal shift analysis will presented as a supplement to this report.

Step 7
The results of step 6 were presented to the operators in the project asking them to compare them with transport prices per load unit they know about (from themselves or from other operators). The operators also reacted on the feasibility results of step 6, confirming or critically commenting the results. On this basis the initial pilot network design was modified, the result being the final pilot network.

The design process in the project was a longer process producing a trace of preliminary pilot networks. Appendix 4 informs about these networks.

5 Mapping promising Twin hub regions

(R. Konings, Y. Kawabata, J. Kiel, E. Kreutzberger and M. Meijers)

5.1 Introduction

This chapter is focussed on the mapping of transport flows that are relevant in the process of identifying promising bundling networks, which is the subject of chapter 4. In view of identifying promising bundling networks the aim of this transport flow analysis is to find transport relations between seaport and hinterland regions that have too small volumes each to fill a train, but would have sufficient volume to run a train if the load units are bundled with load units of another seaport that are destined to the same hinterland region. In other words, the envisaged result of this research activity is to have a list of regions that potentially can be served by the Twin hub network. The chapter describes the approach that was followed in this transport flow analysis and presents its results.

In the framework of analysing transport flows Zeeland Seaports also performed an analysis of its potential flows that would be suitable for a modal shift from road to rail. The aim of this analysis was to explore if there could be possibilities to develop a spoke service from the seaport region of Zeeland to the hub region (Antwerp or Rotterdam). The results of this analysis are summarized in Appendix 2.

5.2 Approach

5.2.1 Defining the target market

A major starting point for the analysis was the definition of relevant flows to consider. Since the target market for Twin hub train services consists of flows that are too small to enable a train service from an individual seaport, these flows will be currently transported by road. The potential market for Twin hub services has therefore been defined as transport of intermodal load units by road.

The majority of intermodal loads that arrive and leave the seaport are containers that are deep sea related, i.e. they are the land leg of a transport chain that involves deep sea transport. These container flows are known as maritime intermodal flows. In addition, there is transport of intermodal load units (i.e. containers and swap bodies) between the port and hinterland which is not deep sea transport related and has its origin or destination at companies that are located in the port region (so called continental transport). Both these maritime and continental flows are included in the target market.

The possibility that volumes which are currently transported by barge in the hinterland of Rotterdam and Antwerp could be a target market is excluded. Barge transport has a very strong position in the hinterland transport market (in particular because of its low rates) and hence it is not likely that rail transport can strongly compete and capture market share of barge transport.

Short sea shipping is also a cost competitive transport mode. However, as hinterland transport is concerned, short sea shipping is rather expected to be complementary to rail transport than competing with this mode. Rail transport, however, can become a competing mode for short sea shipping for very specific continental intermodal flows (i.e. where rail transport through the Channel can be an option).

5.2.2 Criteria for promising transport volumes

Hinterland regions that, based on their transport volume, are potential promising to develop a Twin hub train service are regions for which the road container flows from Rotterdam and Antwerp together are sufficiently large to implement a train service. ‘Sufficiently large’ means that it enables a train (of 600 meter length) to run break even when it has a frequency of 3 departures per week in both directions. Conform preferences of shippers a frequency of 3 train services per week can be defined as a minimal frequency that is required to offer an interesting alternative to road transport. In order to run ‘break even’ the train should have an average loading degree of about 80%. Hence the joint volume between the seaports and a hinterland region that is needed to run a train is about 20.000 TEU on annual base. An additional criterion is that the volume in one direction is at least 6.500 TEU. If not, the imbalance of flows will be too large to run a train break even. Since it is unlikely that all road container flows will shift to rail when a train service is introduced it is clear that 20.000 TEU should be considered as a threshold volume for regions that may be interesting to develop a new train service. The actual road transport volume in a region that can be captured by rail depends on the competitiveness of rail to road transport to that region. A modal shift analysis is needed to assess the real volume of road containers that may shift to rail transport.

5.2.3 Geographical focus of the analysis

A first step in the demarcation of the geographical scope of the transport flow analysis has been the definition of relevant European corridors that include the Dutch and Belgian seaports (notably Rotterdam and Antwerp). First of all, these are the corridors that begin or end in the seaports of Rotterdam and Antwerp and cover the following directions South (France, Spain, Italy), Southeast (Switzerland, Austria), East (Germany, Poland and Czech Republic), North (Sweden) and West (United Kingdom). In addition, there are the corridors that concern freight flows that do not begin or end in the Dutch or Belgian seaports, but in which the location of seaports of Rotterdam and Antwerp offers opportunities to bundle flows in these corridors with those in the corridors in which Rotterdam or Antwerp are begin or end point. From this point of view the most relevant corridors that have been selected here are the corridors United Kingdom (England) – Germany/Poland and United Kingdom (England) – France.

A next step in the process was the definition of regions. The transport flow analysis should be performed at a disaggregated level, i.e. a regional level, to enable conclusions about potential train services. On the one hand two port regions, i.e. Rotterdam and Antwerp, had to be defined and on the other hand the regions in the hinterland. It is clear that the definition of a region relates to what is considered to be the service (catchment) area of the terminal in that region regarding to the attraction of flows. The larger the regions are defined, the larger the transport flows will be, but in a greater region the transport volume is in principle more dispersed. As a consequence the average pre- and post-truck haulage distance increases, which makes intermodal rail transport less cost competitive to road transport.

In defining the regions the availability of transport flow data had also to be taken into account. Data could be obtained at the so called NUTS 3 level, which is the lowest administration level that is commonly used in EU-wide statistics. The availability of data for NUTS 3 regions enables to aggregate data to a higher level (e.g. NUTS 2) and hence flexibility in defining the size of regions.

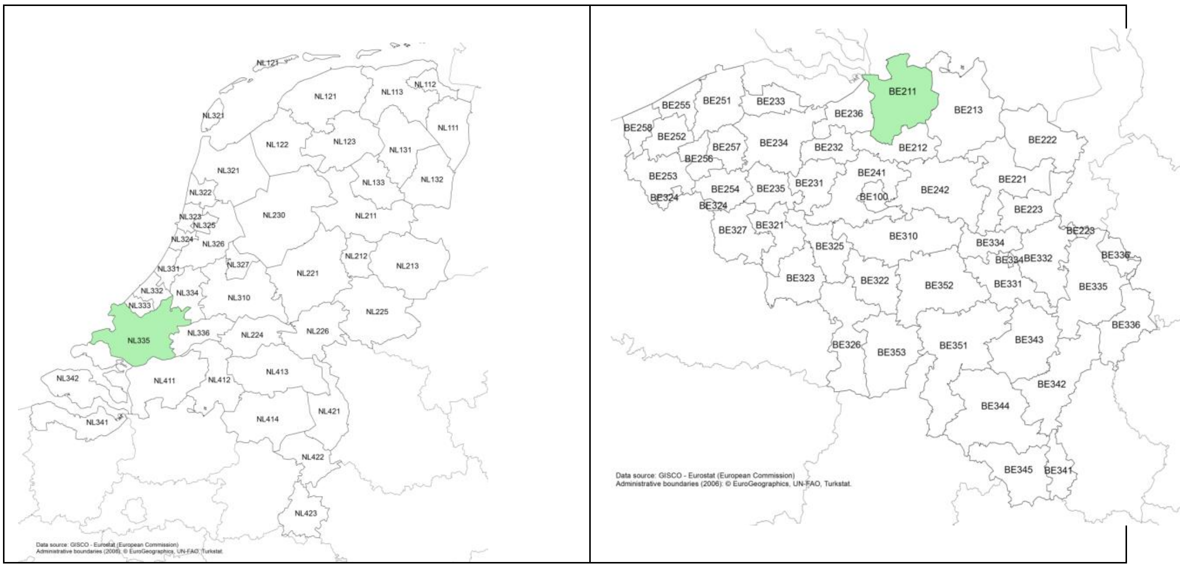
With respect to the size of port regions two scenarios have been elaborated: 1) small port regions and 2) large port regions.
Small port regions: the size of the region is limited to the port areas of Rotterdam and Antwerp. These areas include all container terminals (deep sea and rail terminals) of the seaports as well as the major clusters of port companies that generate transport in intermodal load units. The majority of intermodal load units that arrive and leave from these regions to the hinterland regions consist of maritime containers (i.e. the land leg of a deep sea transport chain). In addition, there are the inbound and outbound flows of intermodal load units that have no relation to deep sea transport (the continental flows) and which are generated by the companies located in the port area. The port area of Rotterdam consist of the NUTS3-region ‘Groot Rijnmond’. The port area of Antwerp covers the NUTS3-region ‘Arrondissement Antwerpen’ (see figure 5.1).
Large port regions: the motivation to define also larger port regions is that the catchment area of rail hub terminals in the port of Rotterdam and Antwerp may exceed the borders of their own port areas. Whether it can be cost effective to deliver a container over a relative large distance by truck to a rail terminal in Rotterdam or Antwerp will largely depend on the rail distance of the train service into the hinterland. The larger the rail distance the larger the pre- and post-truck haulage can be.
The large port region of Rotterdam covers the West- and Southwest of The Netherlands. The large port region of Antwerp covers partly the province of Vlaanderen and the province of Brussels (see Figure 5.1).
In this scenario of large port regions the inbound and outbound flows will be larger than in the scenario with small port regions. The larger flows are the result of additional continental flows.
Concerning the size of hinterland regions two geographical levels have been included, the NUTS2- and NUTS3 level. Table 5.1 shows the number of regions at different geographical levels.

Table 5.1 Number of regions per country at different geographical levels (NUTS1, NUTS2 and NUTS3)

Country	NUTS 1	NUTS 2	NUTS 3
Germany	16	39	429
Poland	6	16	66
Czech Republic	1	8	14
France	9	26	100
United Kingdom	12	37	133
Austria	3	9	35
Switzerland	1	7	26
Italy	5	21	107
Spain	7	19	59
Sweden	3	8	21

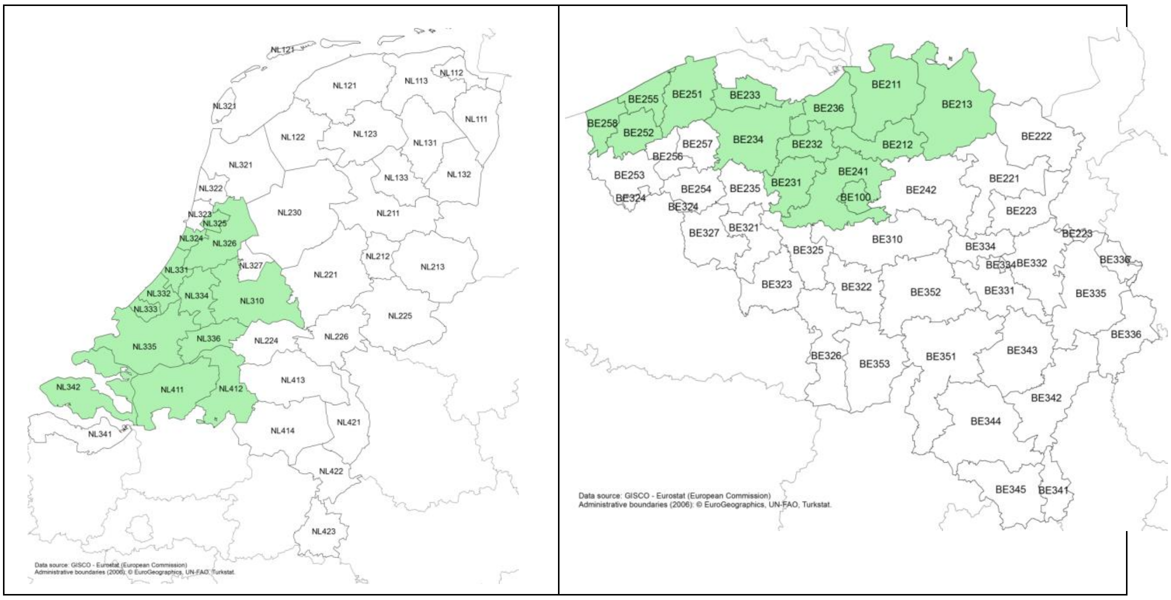
Source: derived from Eurostat, 2007.

Figure 5.1 Small port regions of Rotterdam and Antwerp



Source: drawn by Meijers, TUD-OTB

Figure 5.2 Large port regions of Rotterdam and Antwerp



Source: drawn by Meijers, DUT

5.2.4 Data availability and preparation

The specific data needed for the transport flow analysis concerns data that is not directly available at statistical offices like Eurostat. The common procedures to develop statistics regarding road transport do not allow to obtain data on such a low geographical level. Therefore it was needed to estimate these freight flows. This is a task that has been performed by Panteia.

Two main data sources have been used from the ETISplus project (http://www.etisplus.eu). These contain trade data and transport data respectively for the year 2010, being the most recent year for which the dataset could be constructed. These sources are complementary and can both be used to assess freight volumes.

Data have been constructed in two steps:
Step 1: Select the transport flows which are related to the study area from ETISplus transport data
Step 2: Estimate the percentage of the container transport flows per transport mode, i.e. road transport
The transport matrices contain information of goods flows per mode of transport. The metadata are available via the share point site:
http://www.etisplus.eu/data/MetaData%20Documents/D6%20Report-%202010%20Database%20and%20Methodology/05-D6-Final-V1.3-CH19-CH28%20W97.pdf

In view of the scope of the Twin hub project the road freight flows should consist of unitised transport (cargo in intermodal load units) covering containers, swap bodies and piggy back units. As regards the maritime flows (land leg of deep sea chains) the containerisation rate is known from statistics, but this is unknown for continental flows. Containerisation rates have been derived from the trade statistics of the involved countries. A containerisation rate per cargo type (defined per country-to-country relation) is used to transform ‘cargo in tonnes’ to ‘number of TEU’. A consequence of deriving the total unitised freight flows for road in this way is that it is not possible to make a distinction between the maritime and non-maritime (continental) flows.
The data reflect the transport performances of EU-27 transport companies only. It is unlikely that this leads to a biased estimation of flows, because the majority of road transport companies that are active in the corridors that were defined are from the EU-27 countries.
Furthermore, the data relate to cargo transport only: no transport of empty containers. Data on empty container flows are available at country-to-country level only. In road transport about 15% of all containers transported internationally are empty. Although empty road containers may also form trainloads for Twin hub trains it is not opportune to include empty containers in the target market. The development of a new train service would rather be based on cargo flows than empty containers, in particular because empty container transport is a very volatile transport business.

5.2.5 Structured process to find promising regions

The selected countries for the analysis contain many regions, particularly at NUTS 3 level and for the countries of Germany, United Kingdom and France (see table 5.1). Moreover, there are large differences in the size of regions between the countries. A region of NUTS 3 level in a large country may have about the same size as a region at NUTS 2 level in a small country. Due to the large number of regions it was decide to take a step by step approach: peeling the potential promising regions by looking first at the threshold volume (20.000 TEU) for the regions at NUTS 2 level and as a next step at NUTS 3 level. Evidently it is needed to take somehow the real size of a region into account when assessing whether a region is promising in generating transport flows.
An additional important argument for this peeling approach was the fact that not only the flows between the seaport regions and hinterland regions had to be mapped, but also continental freight flows between hinterland regions (e.g. UK and Poland) since

such flows could be bundled as well with the inbound and outbound flows of the seaport regions.

5.3 Results

In order to identify promising regions to which Twin hub train services could possibly be developed the container road transport flows between the (small) port regions of Rotterdam and Antwerp on the one hand and the regions in the hinterland on the other hand have been mapped. The mapping of flows initially focussed on the small port regions (NUTS 3 level). Choosing for the small port regions implies a conservative approach in estimating the size of the flows. The considered size of the hinterland regions is the NUTS 2-level.
As regards the East corridor regions in Germany and Poland showed substantial road container volumes, while regions in the Czech Republic did not. As the other corridors are concerned Italy appeared to have one region exceeding the threshold volume of 20.000 TEU, while France has several promising regions. The distinction between promising and non-promising regions has been visualized in figure 5.3 for Germany, Poland and the Czech Republic and in figure 5.4 for France. The promising regions have container flows from Rotterdam and Antwerp that together exceed 20.00 TEU on annual base. These regions are darkly coloured in the images. The images clearly show that several regions have only potential for new train services if the volumes of Rotterdam and Antwerp are bundled. Furthermore, the images also make clear that the promising regions are predominantly found at the border regions of France and Germany. Moreover, those regions having the largest volumes are at the shorter distances from the seaports of Rotterdam and Antwerp. These observations confirm the general notion that transport volumes tend to get smaller if the transport distance increases, but there may be exceptions. For instance, the region of Slaskie in Poland had a volume of 23.000 TEU and Rhone-Alpes in France more than 26.000 TEU.

Figure 5.3 Container transport volumes by road (in 1.000 TEU) between the seaport regions of Rotterdam and Antwerp and hinterland regions in Germany, Czech Republic and Poland, 2010

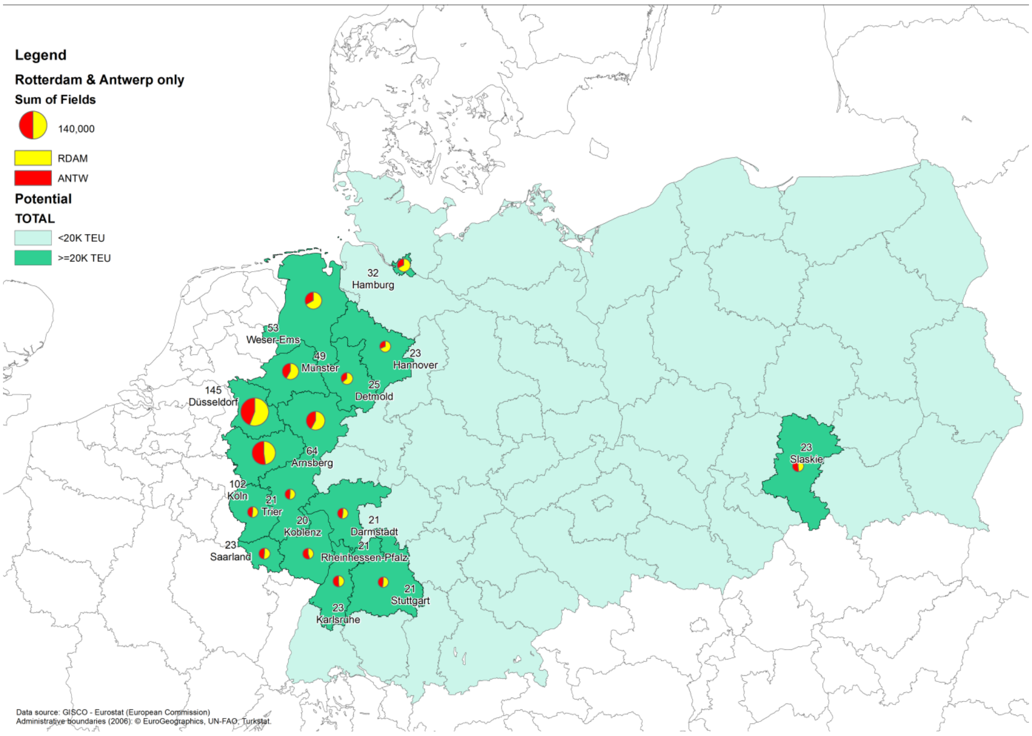
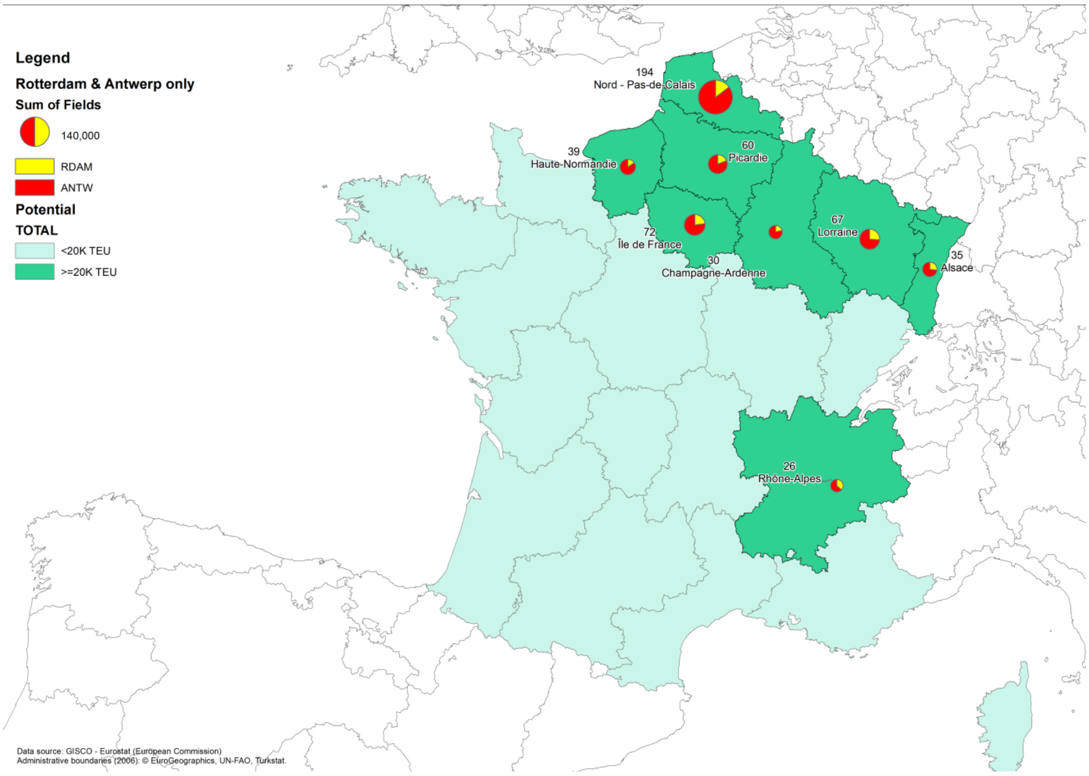
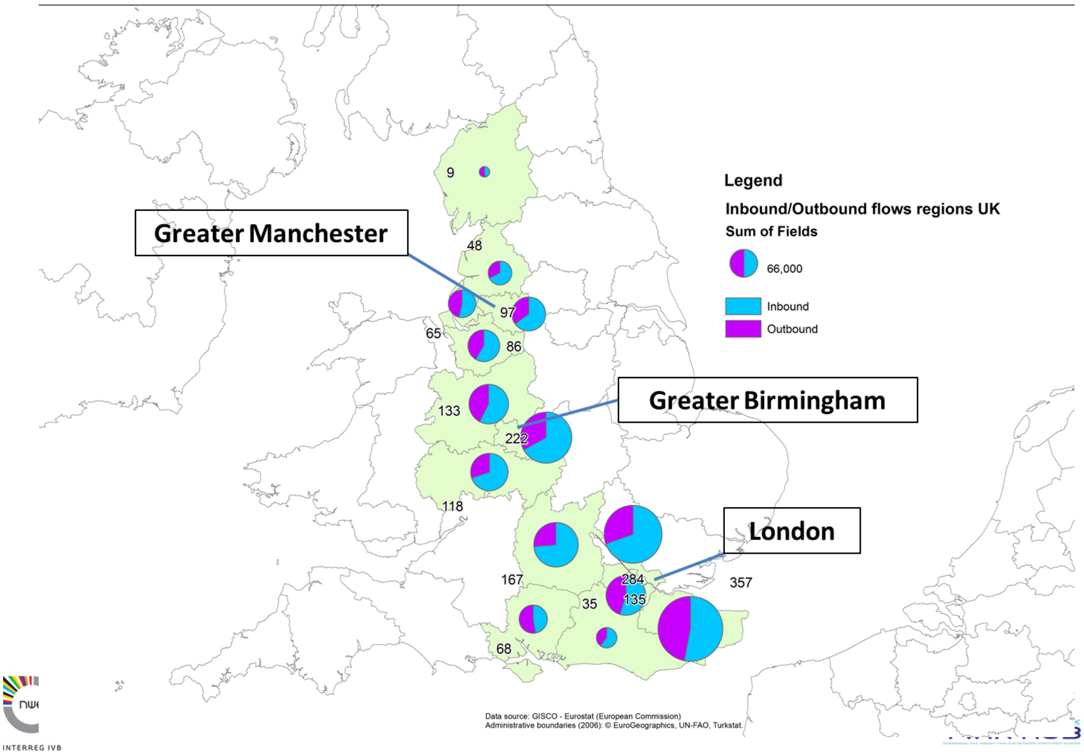


Figure 5.4 Container transport volumes by road (in 1.000 TEU) between the seaport regions of Rotterdam and Antwerp and hinterland regions in France, 2010



The Twin hub concept is primary focussed on hinterland transport, but the combination of maritime and continental flows can enlarge the scope and improve the performances of the concept. This holds for the core seaports in this study, Rotterdam and Antwerp, but even more for corridors in which the continental flows, so to speak, pass by Rotterdam and Antwerp, such as the intermodal flows between United Kingdom and parts of the European continent (e.g. Germany, Czech Republic and Poland).
To find potentially interesting regions in the UK concerning flows into the East corridor (Germany, Czech Republic and Poland) the following steps have been taken. A first selection consisted of only regions in England. Next the total inbound and outbound flows of these regions at NUTS 2-level have been mapped to find major cargo attracting and generating regions. Following this step the flows were looked at more detail (i.e. NUTS 3-level) and, in addition to flow size considerations, the possibilities of competition from the short sea shipping chain in linking these UK regions with the ports of Antwerp and Rotterdam were considered. That is to say, UK regions at a distance from a UK seaport were considered to be more promising for a train service (through the Channel) to Antwerp and Rotterdam[9]. Train services from these regions will be more competitive, because in the short sea shipping chain relative high pre- and post-truck haulage costs are involved. According to these criteria the following regions were considered as relevant for the analysis: Greater Manchester region (North West England), Greater Birmingham region (West Midlands) and London region (South East England).

Figure 5.5 UK regions that are potentially relevant for Twin hub train services

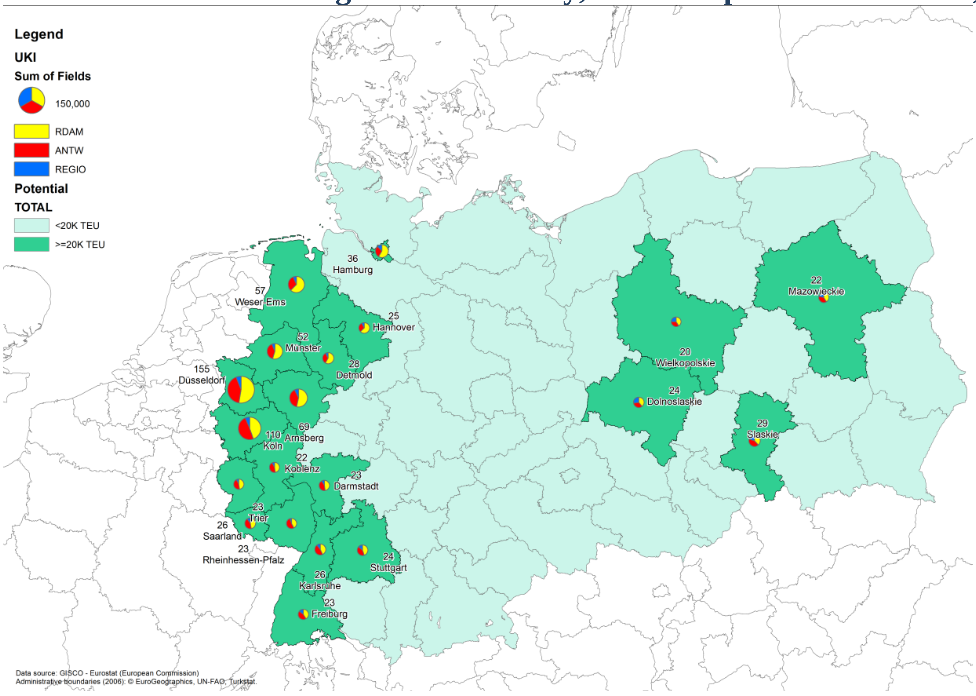


[9] In addition to the distance to the seaport also the importance of the UK seaport in the network of short sea shipping services was considered. In particularly, the seaports at the Eastside of England are much better embedded in short sea shipping service networks than the seaports on the Westside of England. Moreover, the sailing distance from the Eastside ports to Rotterdam and Antwerp is much shorter than for the Westside ports.

criteria the following regions were considered as relevant for the analysis: Greater Manchester region (North West England), Greater Birmingham region (West Midlands) and London region (South East England).

Including the flows of these UK regions results to an increase of promising regions and also to large volumes to the regions that were already identified as promising based on the combination of Rotterdam and Antwerp flows only. Combining the flows of the London region with the Rotterdam and Antwerp flows leads to the largest increase of flows. Figure 5.6 and 5.7 show the promising regions and their road container volumes when the flows of Rotterdam, Antwerp and London are bundled.

Figure 5.6 Container transport volumes by road (in 1.000 TEU) between the seaport regions of Rotterdam, Antwerp and the London region and hinterland regions in Germany, Czech Republic and Poland, 2010



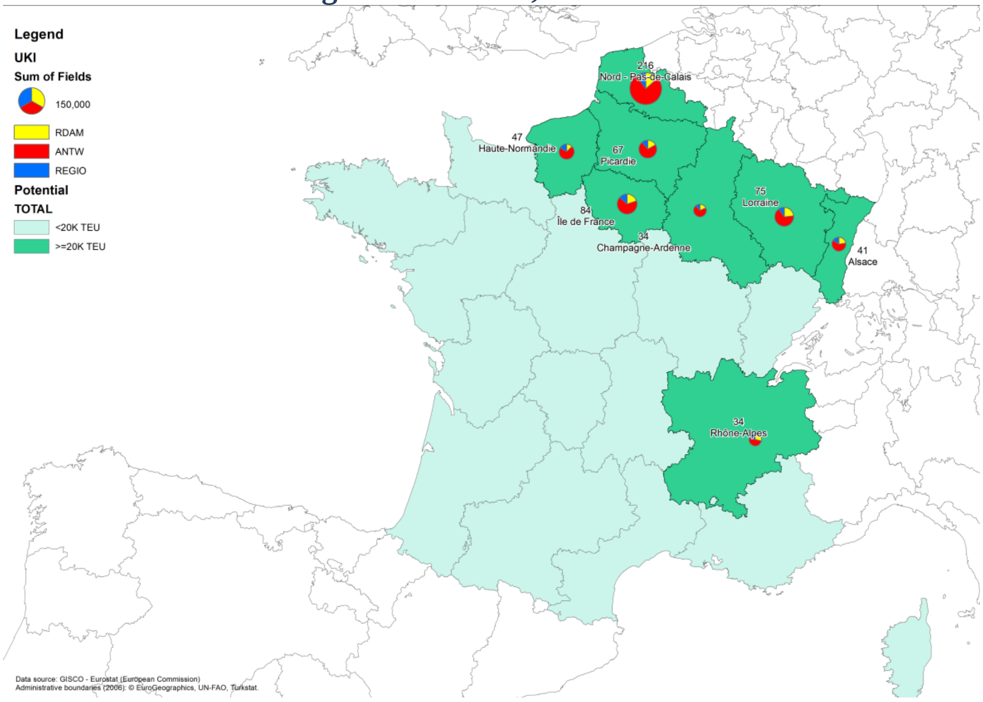
5.4 Conclusions

The aim of the transport flow analysis was to map intermodal transport flows between the seaports of Rotterdam and Antwerp and their hinterland to find hinterland regions that potentially can be served by a Twin hub network. The focus in identifying these regions was on road container transport (considered as the target market for new train services) and on flows in which the joint volume of the Rotterdam and Antwerp flows exceeds 20.000 TEU on annual base (being a threshold volume to enable a train service).

Accordingly, regions with promising transport volumes were found in:

- Poland: Slaskie.
- Italy: Lombardia.
- Germany: several West German regions (border regions).
- France: regions in North France and Rhone Alpes.

Figure 5.7 Container transport volumes by road (in 1.000 TEU) between the seaport regions of Rotterdam, Antwerp and the London region and hinterland regions in France, 2010



Next it was shown that combining these Rotterdam and Antwerp flows with flows form the UK increases the possible hinterland destinations for train services in a Twin hub network and also the viability of these train services, because of larger flows.
The findings regarding potentially promising regions are, however, only indicative as they are based on volumes of flows only. A cost comparison between intermodal rail transport and unimodal road transport is needed to define really promising hinterland regions to start new rail services.

Table 5.2 Volumes of bundled flows between seaport and UK regions and hinterland regions (x 1.000 TEU)

	R'dam + Antwerp	**R'dam + Antwerp + Manchester**	**R'dam + Antwerp + Birmingham**	**R'dam + Antwerp + London**
POLAND	Slaskie (23)	Slaskie (24)	Slaskie (26)	Slaskie (29)
			Dolnoslaskie (20)	Dolnoslaskie (24)
				Wielkopolskie (20)
				Mazowieckie (22)
FRANCE	Rhone-Alpes (26)	Rhone-Alpes (28)	Rhone-Alpes (30)	Rhone-Alpes (34)
	Alsace (35)	Alsace (36)	Alsace (38)	Alsace (41)
GERMANY		Freiburg (20)	Freiburg (22)	Freiburg (23)
ITALY	Lombardia (28)	Lombardia (30)	Lombardia (34)	Lombardia (40)

6 The Twin hub pilot network

(E. Kreutzberger and R. Konings)

6.1 The pilot network decided on in 2014

Knowing the promising Twin hub regions and having potential customers in mind, the network design process could take place. The design was an iterative process between the rail operators in the pilot, supported by research activities. The three rail operators in the project – intentionally and in practice – had the dominant voice in this process, as they are the market specialists recruiting customers and as they are to carry the commercial risk. The other project partners could oppose to or second the proposals of the operators on the basis of network theoretical considerations, like principles of bundling or of operational efficiency. The port authorities had additional arguments, especially which connections strengthen the position of the seaport.

6.2 The train connections in the Twin hub pilot network

The final Twin hub pilot network decided on by the project – we call this the 2014 pilot network – consists of the following connections (Figure 6.1):

1) Russell: London Barking – Dourges (near Lille, France) – Rotterdam RSC. Three departures per week and direction;
2) IMS Belgium: Rotterdam Maasvlakte – Antwerp Zomerweg – Frenkendorf (Basel, Germany). Three departures per week and direction;
3) ERS: Rotterdam RSC – Sosnowice (Slaskie, Poland); Three departures per week and direction.

Dourges, on request of Russell, also in the interest of the port of Rotterdam[10] and with consent of the project and INTERREG, has been added as a third hub to the Twin hub concept. The seaports in its (potential) service area are smaller than Rotterdam and Antwerp, but it has the UK, geographically functioning like a seaport, in its hinterland. And it lies in the middle of a very transport intensive region (Figure 5.4). Dourges can be seen as a gravity point of Twin hub flows.
The Dourges terminal is relative new. It primarily serves the region, with trains running to about 10 terminals in France. The terminal increasingly also functions as gateway with rail-rail transhipment between French and northern trains, in other words the begin-and-end terminal Dourges also carries out modest amounts of rail-rail transhipment. Trains between the UK and Antwerp automatically more or less pass Dourges.

The 2014 network, contrary to the pilot network the rail operators discussed in 2013 (Figure A4.4 A in Appendix 4) appears rather disintegrated. The 2013 network clearly had a central hub (Mainhub) and all trains passed this hub. The 2014 pilot network has no central hub, but several terminals with Twin hub rail-rail transhipment. The

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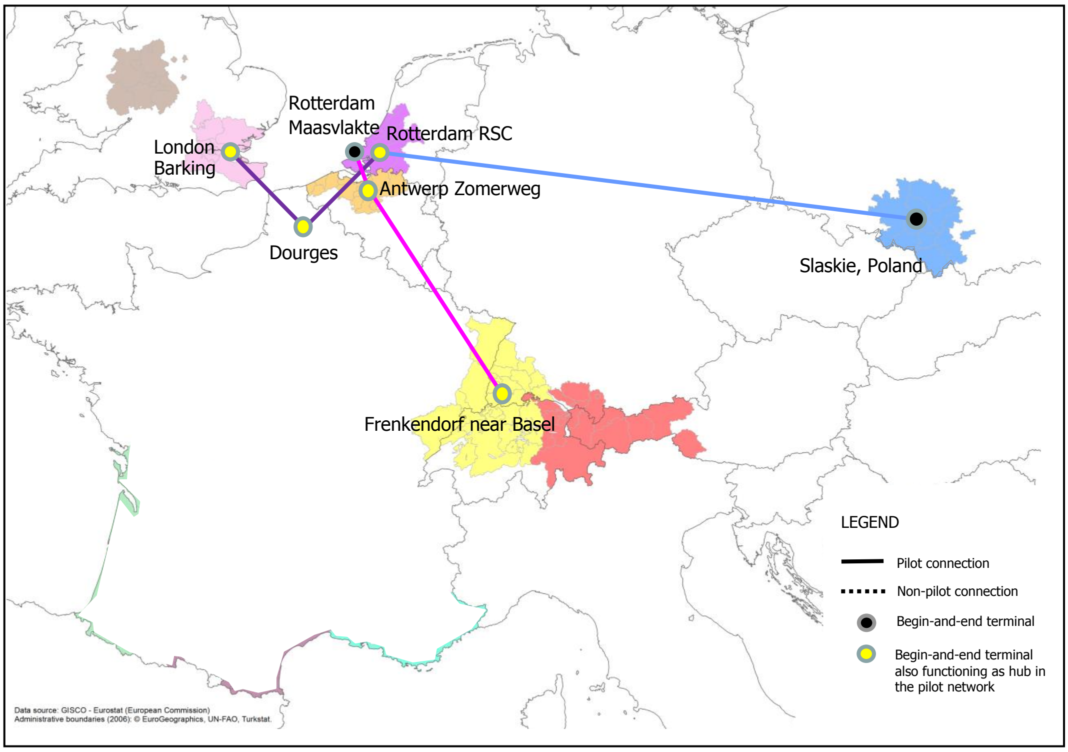
[10] The Port of Rotterdam would like a connection Rotterdam-Dourges to be implemented, as this improves the port's embedment in the network of European rail services. There already is a rail connection Antwerp-Dourges (operator Greenmodal), which however is very short and said to be less profitable.

Basel connection in the network looks like a stand-alone configuration with no relation to the rest of the network. Two spokes, the UK and the Poland one, still are interconnected, but rather in a gateway-like manor (Section 2.3.6), which is at a begin-and-end terminal, the RSC, than at a hub. Is this still a Twin hub network?

Figure 6.1 The Twin hub pilot network 2014



The answer is yes, but in a different way than had been anticipated. Figures 6.2 and 6.3 give the clue. The pilot trains cooperate with non-pilot trains (Figure 6.2) in a way that the Twin hub logic is still present (Figure 6.3). De facto we are dealing with three hub-and-spoke networks, centred around three hubs (Dourges, Antwerp Zomerweg and Rotterdam RSC), all part of the Twin hub network. The result rather represents a later phase of the Twin hub implementation than the first phase in which there is only one pilot hub-and-spoke network.[11] One could also say, that the hub function in the 2013 pilot network (Figure A4.4 A in Appendix 4) in the 2014 pilot network has been de-concentrated to several hubs while also much more trains are involved in the 2014 than in 2013 network.

The Twin hub logic is present in the 2014 network in the following way.

- **Hub-and-spoke network 1**: the UK train meets trains from other seaports at the terminal **Dourges** v.v. in order to exchange load units from and to French trains (Figure 6.3 A). The other trains are from Novatrans, Naviland and Greenmodal.
- **Hub-and-spoke network 2**: the Basel train meets trains from other inland terminals at the terminal **Antwerp Zomerweg** in order to exchange load units to

[11] With three pilot train connections in the sense of the Partnership agreement and Application form.

Figure 6.2 Connections to be attached to the Twin hub pilot network

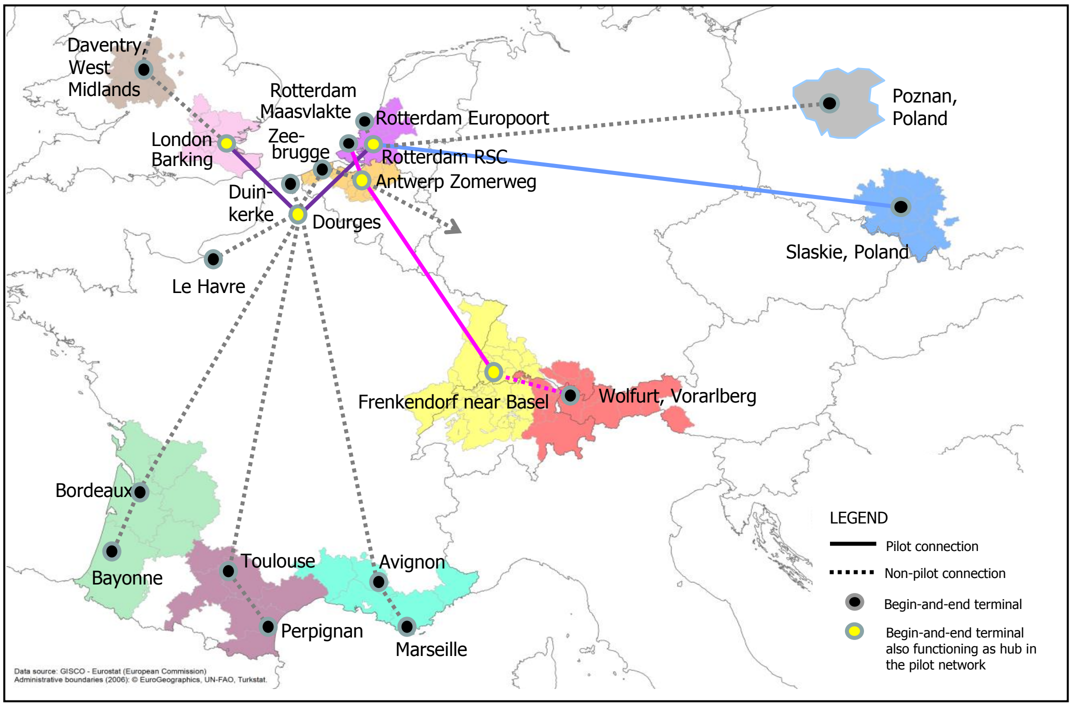
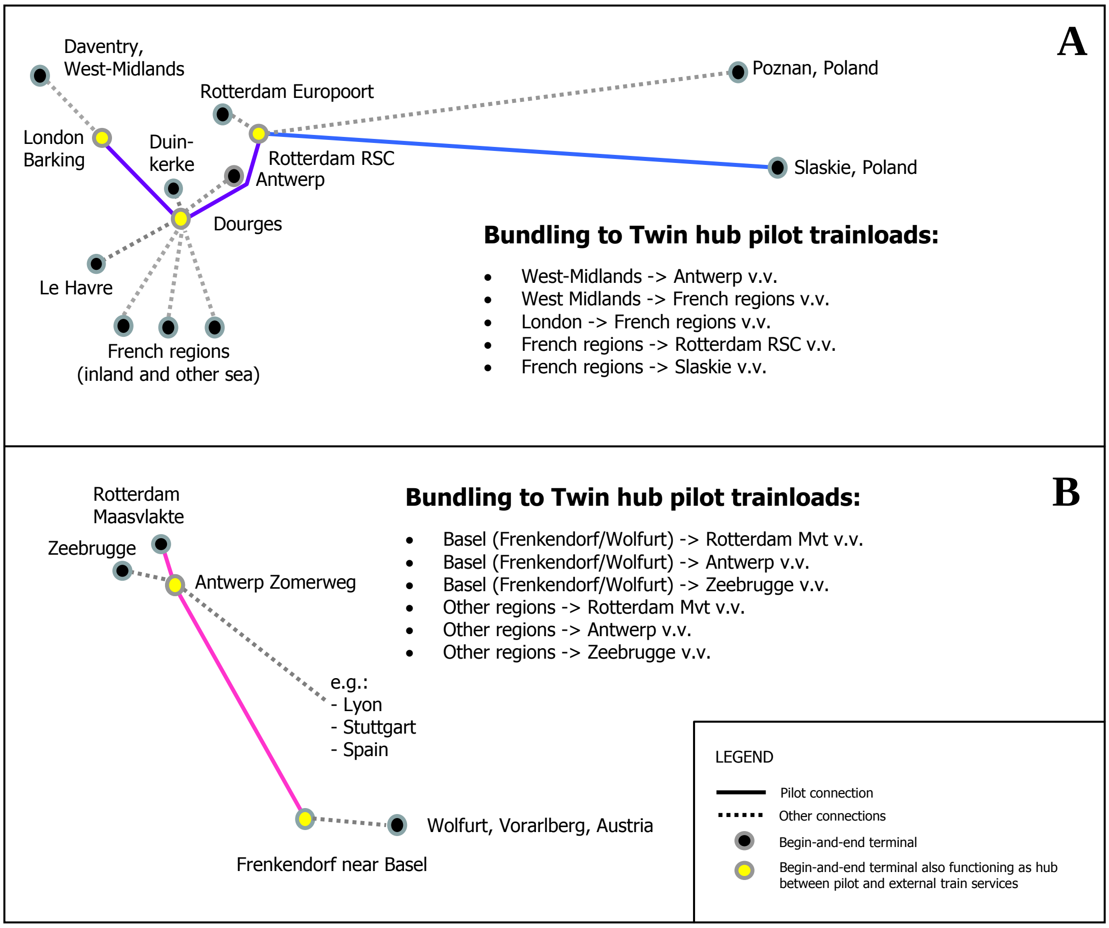


Figure 6.3 Twin hub logic in the pilot network 2014



different seaports (Antwerp Zomerweg, Rotterdam Maasvlakte and Zeebrugge) v.v. (Figure 6.3 B). The other trains are from IFB.

- **Hub-and-spoke network 3**: the UK train at the terminal **Rotterdam RSC** exchanges French load units to different Poland trains (all ERS trains) v.v. Employing port-internal transport, the Basle train can also deliver Antwerp-Poland load units to the Poland trains (Figure 6.3 A).

The Twin hub logic is also manifest for the Basel train connecting Switzerland (and Austria) with Antwerp/Rotterdam. IMS already runs four trains between Rotterdam and the region Basel. They are completely filled having no capacity reserves for the growing demand on this transport relation. The firm also has customers with Basel-Antwerp flows, but these are too small to justify a train service. The solution to these problems is to bundle the growth volumes for Rotterdam and the small volumes for Antwerp to a trainload for a new train connection, namely Basel-Antwerp-Rotterdam or Basel-Rotterdam-Antwerp. On the segment Antwerp-Rotterdam the trainload is rather small because Antwerp or Rotterdam loads have been off-loaded. The train needs to be filled with other load units for which there are two major options. One is that the Rotterdam-Poland train of ERS also has Antwerp-Poland load units. The other option is to receive Rotterdam load units from other (pilot-external) trains which begin and end at Antwerp or Zeebrugge. A Zeebrugge train can benefit from this exchange in a symmetric way: at Antwerp it receives load units from the Basel train to fill the train on the segment Antwerp-Zeebrugge (Figure 6.3B).
A point of attention is the roundtrip design. A train roundtrip Basel-Rotterdam or Basel-Antwerp takes 3 days. As a week has 7 days, one of the 2 roundtrips in the week lasts 4 days. The fourth day is unproductive unless the train visits additional rail terminals along. Twin hub network is a relevant option to use the fourth day productively. The train can visit Antwerp AND Rotterdam. If several trains do so, the service frequency aimed at can be achieved.

The (temporal) closure of the Mainhub Antwerp implies that:

- there is no true hub terminal available in the whole seaport range Zeebrugge - Amsterdam;
- Antwerp Zomerweg, a begin-and-end terminal for the rail system, will take over the hub activities and function as hub and begin-and-end terminal in the pilot network. The spoke in the port of Antwerp disappears (compare Figure A4.4 A and B in Appendix 4);
- most flows between the Antwerp hub (Zomerweg) and the other rail terminals in the seaport of Antwerp are moved by barge or truck.

6.3 Principle differences between the pilot network 2014 and the initial concept Twin hub concept

The pilot network differs from the initial Twin hub concept in several ways, some of which represent compromises to constraints of practice, and others represent improvements towards the initial concept. Compromises are:

- the **absence of a separate hub node**. Instead begin-and-end terminals also function as hubs. Rotterdam never had a real hub terminal, due to – as far as the complex bundling is concerned – its tradition to bundle intermodal rail flows linewise. Antwerp's Mainhub terminal has been closed temporarily end of 2013. The closure does not indicate a failure of the functionality of the Mainhub, but of its main user, the domestic NARCON network;

- the **absence of simultaneous train visits** and direct transhipment between trains at the hub. Instead the trains visit the hub sequentially and all rail-rail exchange takes place via the stack. The main reasons for this change is the history of development (the pilot services and the rail-rail exchange were added) and for Rotterdam RSC also the lack of terminal capacity. As time progresses providing time to synchronise the exchanging services at the hub, the urgency declines as also the service frequency increases (Section 2.3.2). The challenge for rail operators then is to let the service survive in the low frequency phase;
- to have **load units visiting more than only one hub** during their land journey. The benefits of increasing the flow size are larger than the disadvantages of an additional hub in the chain. For long distances (as France-Poland) the multiple hub stop is not too much of a disadvantage, unless there are competing services with less hub visits;
- due to **interoperability restrictions** between the UK and the continental rail network. Continental wagons can run up to the terminal London Barking and no further in the UK, given **smaller gauges** in the UK network. If a continental train wants to move further than London it has to use UK wagons also on the continent. And these are more expensive. An alternative is to transfer load units between UK trains and continental trains in London, generating costs and reducing the competitiveness of rail towards short sea. Nevertheless, connecting West Midlands or Manchester to the continent by rail can be sufficiently competitive;

Some of these compromises will vanish when the Twin hub network evolves to a larger one than the 2014 pilot network.

The most important improvement of pilot operations towards the initial Twin hub concept is the extension of modes. **Barge transport** is increasingly seen as a welcome supplement to collect, distribute and integrate flows of different rail terminals to trainloads, in particular because of its low costs. This at least is the case on the level of a large seaport, say within Antwerp or Rotterdam. In Antwerp barge transport has already significantly substituted the integration of flows by the rail system.

This new notion does not imply that rail hub-and-spoking in the seaports is unavoidably becoming abundant. Numerous rail terminals in the port don't have a waterside. And the barge system is slow, a disadvantage in particular for continental inter-seaport transport. However it could mean, that the ideal location of a true hub terminal is a trimodal one so that the terminal can – next to efficiently handling rail-rail transhipments – also deal with barge-rail exchanges. Slow and cheap barge services can compensate for costly imperfections in the rail network.

6.4 The choice of hub location

6.4.1 The criteria

The choice of hub location refers to two levels, the hub region and – within that – the concrete node. The choice of **hub region** (Rotterdam, Antwerp, Dourges):

- primarily depends on the **distance** implications of a hub region for the involved connections. If the main direction is the northeast corridor, the region Rotterdam is the logic hub region. If the main direction is the southwest corridor, the region Antwerp or Dourges is the logic hub region. For directions in between the two it might be the Rotterdam or Antwerp region;
- also depends on the **other characteristics** of the hinterland routes, such as the freedom to choose traction (and in this way influence costs and reliability of traction) which still differs per country or corridor[12], the size of capacity reserves in critical parts of the rail network, or the perception of involved operators. If the involved operators do not agree on the same hub region, network configurations with multiple hub regions need to be invented.

The **hub node** to choose **within a hub region** depends on:

- its **suitability**, referring to:
  - **locational network characteristics**:
    - Is the hub located near the entry of the seaport or far away from the entry? For instance, the Maasvlakte terminals in Rotterdam or Combinant terminal in Antwerp lie rather far away from the port rail entry.
    - Can all hinterland corridors be reached from the hub without large detours or without large operational efforts? If yes, we call the location ***corridor-neutral***, otherwise ***corridor-specific*** (see also Kreutzberger and Konings, 2013c). An example for the port of Rotterdam (Figure 6.4): From Kijfhoek all hinterland corridors can be reached easily, making it a corridor-neutral hub-location. Valburg, located along the Betuweroute about 100 kms from Rotterdam, causes larger detours for flows on the Antwerp-corridor, making it a corridor-specific hub location;
  - **infrastructure network characteristics**: is there, from the rail port entry, a track per direction to the envisaged hub node, and is this electrified or not?
  - **logistic network characteristics**: which rail operators are using the hub, making it easy to exchange load units between the envisaged connections?
  - **terminal characteristics**: are the tracks suitable for efficient rail-rail transhipment, meaning:
    - are they sufficiently long so that splitting the train in two or more groups can be avoided?
    - is there a larger number (like 5 or more) of tracks beneath the cranes?
    - is internal transport possible by other systems than the cranes connecting the front of some trains with the back of other trains?
  - **shunting yard characteristics**: is the shunting yard suitable for efficient rail-rail exchange of wagon groups, meaning:
    - is it flat so that shunting locomotives can easily enter the yard from all required sides?
    - does it have a larger number (like 5 or more) of tracks for sorting?
    - are its tracks long enough to accommodate a whole train?
    - is the yard electrified?
  - **barge accessibility**: this characteristic is one not required for the initial Twin hub perception, but – given the argument in Section 6.3 – of increasing relevance.

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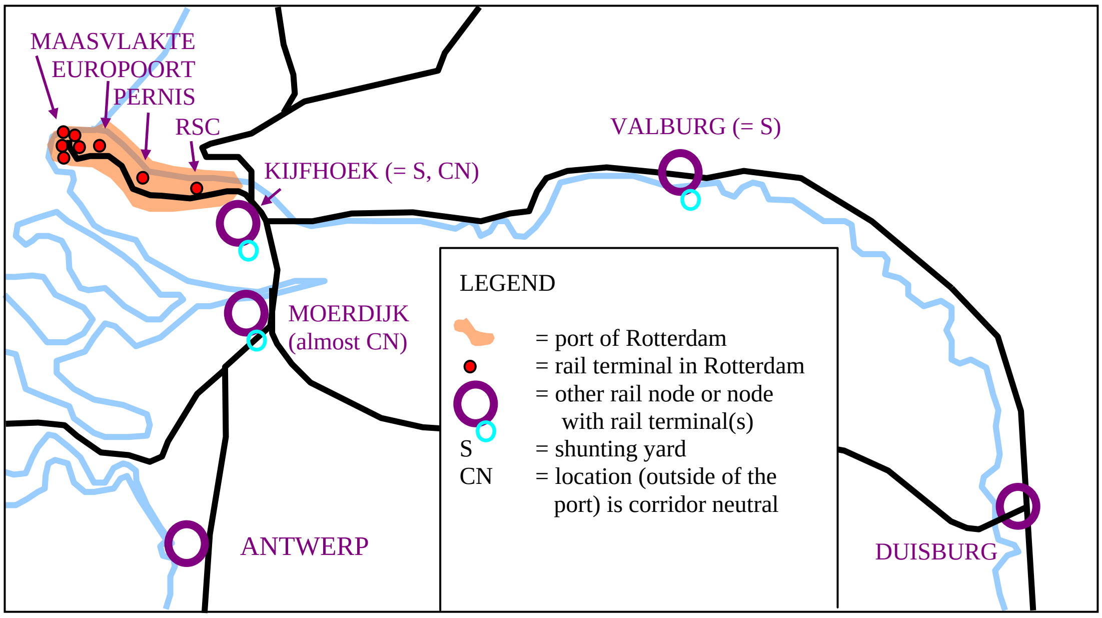
[12] For instance the dependency on NMBS traction in Belgium is rather large making some operators hesitating to choose Antwerp as a network's hub.

- its **availability**. This is about whether the node is public (= to the disposal of more than one rail operator) and neutral (= competing rail operators are treated equally). Availability also addresses the capacity of the envisaged node: does the capacity in quantity (= number of trains and load units?) and quality (= at which times?) respond to the demand for rail-rail exchange?

Figure 6.4 Potential "Rotterdam" hub locations for the Twin hub pilot



In addition to these functional requirements :

- the hub terminal (node) needs to be a neutral = (functionally) public one;
- the terminal operator or the other rail operators using a node may be of importance for the pilot rail operator, for instance to support local operations or administration or because of bundling perspectives.

6.4.2 Hub nodes for the pilot within the region Antwerp

Antwerp has numerous flat shunting yards in the seaport, many of them also having train-long tracks. The primary interest of IMS was terminal transhipment. Several terminals respond well to one or more of the performance types mentioned above (Table 6.1).

For IMS the close cooperation with IFB at Zomerweg terminal is of interest: cooperation in local operational terms as well as wanting to exchange load units with IFB trains. Via IFB trains IMS load units can also be moved to the seaport Zeebrugge. Also there are relevant train connections from southern Europe that are promising to provide load for the IMS segment Antwerp-Rotterdam.

Table 6.1 Rail terminals in or near the seaport of Antwerp (selection) and their suitability for rail-rail exchange

	Mainhub (IFB)	Zomerweg (IFB)	Cirkeldijk (IFB)	Muisbroek (Hupac)	Europa (Hessenatie)	Combinant (Hupac)	Muizen (Ambrogio)	Dourges
Location terminal inside the port is close to the rail port entry	Yes	Yes	(Yes)	(Yes)			Outside the port	Outside the port
Location outside the port is corridor-neutral	Inside the port	Inside the port	Inside the port	Inside the port	Inside the port	Inside the port	Yes	
Terminal layout is suitable for large amounts of rail-rail transhipment	Yes			Yes	Yes	Yes		
Rail terminal can more or less directly be accessed by barge		Yes	Yes	Yes	Yes			

6.4.3 Hub nodes for the pilot within the region Rotterdam

Kijfhoek near Rotterdam (Figure 6.4) is a gravity shunting yard and therefore unsuitable for wagon group exchange. The flat shunting yards in the seaport all date back to the age of wagonload transport, and haven't been adjusted to increasing train lengths, contrary to Antwerp. Exchanging wagon groups at these locations therefore principally requires first to split the exchanging trains, making the exchange type complicated and more expensive. Valburg has a flat shunting yard, however is a corridor-specific location. For the pilot it also has the disadvantage of not having staff, meaning that its users need to provide staff, a challenge beyond the scope of the pilot.

The limitations of Rotterdam's terminals to carry out a hub function are larger than those of Antwerp. Many of the terminals in the port lie far away from the entry of the rail system to the port (Table 6.2). This is especially true for the Maasvlakte terminals, lying about 50km west of the port's rail entry. Next to time expenses for trains only visiting the Maasvlakte because of its hub, such operation would imply using the port track (Havenspoor) twice on its entire length or a large part of that, a not very realistic option, as this track is already heavily being used. The most eastern terminal, RSC, is located some 10kms from the port entry. None of the terminals is designed for rail-rail transhipment, the Maasvlakte terminals still having the best layout for such. RSC could, given the limited amount of rail-rail transhipment in the pilot phase, nevertheless be suitable, but its capacity reserves are near to zero. Pernis has short tracks. The location of the rail terminal in the seaport of Moerdijk could almost be called corridor-neutral, but entering the Betuweline from there v.v. is not simple in

operational terms.[13] Other limitations seem to be less important, such as problems when leaving or entering the main track from/to the port of Moerdijk, or the single none-electrified track between the main track and the terminal.
At least quite some terminals can rather easily be accessed by barge.

Table 6.2 Rail terminals in or near the seaport of Rotterdam (selection) and their suitability for rail-rail exchange

	Euromax * (ECT)	DTW * (ECT)	Europoort (P&O Ferries)	Pernis (CTT)	RSC (DB Schenker)	Moerdijk (ECT)
Location terminal inside the port is close to the rail port entry					(Yes)	Oudside the port
Location outside the port is corridor-neutral	Inside the port	Inside the port	Inside the port	Inside the port	Inside the port	(Yes)
Terminal layout is suitable for large amounts of rail-rail transhipment						
Rail terminal can more or less directly be accessed by barge	Yes		Yes	Yes		Yes

* = On the Maasvlakte

Potential hub nodes located further away from Rotterdam are Valburg and Antwerp. Both are, seen from the Rotterdam angle, corridor specific nodes. Valburg is suitable only if the orientation of all services of a Twin hub network is eastwards. It has a flat shunting yard and no rail terminal and could in this regard play a role if the rail operators consider running wagon group trains. However, the shunting yard has no staff. The project would have to employ a staff for the pilot, which is no feasible option.
Antwerp is corridor-specific, a problem for bundling only Rotterdam flows, but appropriate for bundling Rotterdam and Antwerp flows, as Antwerp lies in a gravity point of Twin hub flows. The detour for Rotterdam-Poland flows and trains was accepted during part of the preparation phase of the pilot, making Antwerp – at that time the Mainhub Antwerp – the best hub location, even if Rotterdam was chosen as the hub region.

Duisburg is, given its distance to Rotterdam the most corridor-specific hub location of all potential hub locations mentioned in Figure 6.4. It is of interest only for operators who provide transport only to the eastern corridors. An example is the Rotterdam rail operator DistriRail. The firm, annoyed by the difficulty to bundle flows in Rotterdam and having customers only in the eastern direction, runs trains randomly loaded in the seaport to Duisburg, where all sorting takes place (Nieuwsblad Transport, 2013). Exceptionally, also bundling to other corridors than the eastern ones, take place via Duisburg. The most striking example was Greenmodal (daughter of the French maritime operator CGM-CSA), temporarily bundling its Antwerp-Lyon-Marseille and Rotterdam-Lyon-Marseille flows via Duisburg.

[13] There is no bow allowing trains to enter the Betuweroute directly from the south. The locomotive needs to switch from tail to head at Kijfhoek. The bow of an alternative entry to the Betuweroute (near to Geldermalsen) is too short.

6.4.4 Region Nord-Pas-de-Calais

In the region Nord-Pas-de-Calais the only candidate hub node for Twin hub (like) operations is the terminal Dourges. Its locational characteristics, in particular the access to different rail corridors, are very good. The terminal itself, however, has a layout which mainly suites rail-road and not rail-rail transhipment. For the pilot this is no problem. For substantial amounts of rail-rail transhipment, a retrofit of the terminal would increase the exchange efficiency.

6.4.5 Conclusion

In the regions Antwerp and Rotterdam there are no terminals suitable for rail-rail exchange on a substantial scale, in Rotterdam not because of terminal layouts, in Antwerp not – after the shutdown of the Mainhub – because of locational characteristics. Rotterdam also misses flat shunting yards with sufficiently long tracks which would allow to efficiently form trains of 600m or more length.

For the pilot these limitations are not equally relevant as the amount of rail-rail exchange is limited. Here the main obstacle is availability, in particular in Rotterdam: its only rail terminal in the eastern part of the port and with long tracks (RSC) hardly has any capacity reserves. Receiving terminal slots, let stand slots at preferential times is a large challenge. Receiving terminals slots for simultaneous transhipment between several trains is a mission impossible.

The terminal Dourges is the only rail hub candidate in the region Nord-Pas-de-Calais. It allows to access all surrounding corridors. The terminal layout is mainly suitable for rail-road exchange. For the Twin hub pilot this limitation is no problem.

6.5 The choice of begin-and-end terminal in the Twin hub inland region *(E. Pekin and C. Macharis)*

Following the results of identifying promising inland regions for implementation of Twin hub train services another decision regarding the train services has to be made, i.e. finding the best terminal to serve in the inland regions. Depending on the density of the terminal landscape as well as the size of the region that is envisaged there may be several terminals that could be visited and hence a choice needs to be made. The best terminal to serve is defined as the terminal that offers the greatest market potential for Twin hub train services. Market potential is defined as regions to which Twin hub trains have lower door-to-door costs than unimodal road transport.
For this purpose the Free University of Brussels extended and applied the LAMBIT (Location Analysis Model for Belgian Intermodal Terminals) methodology to the location analysis of intermodal rail terminals for the Twin hub promising routes. This extended model has been named the Euro terminal model.
The model is based on three main inputs: transportation networks (GIS-layers), transport cost (and price) functions, and demand for transport of containers from the regions to and from the sea ports.
The model explores the relative attractiveness of two transportation modes (unimodal road and rail transport) through a price (cost) minimisation model. Following a break-even approach the total sum of transport prices is minimised in the model. Using a shortest path algorithm in ArcInfo, various scenarios are conducted in order to find

the shortest path and the attached transport prices from the Twin hub (Port of Antwerp or Rotterdam) to each NUTS3 region via intermodal terminals and via unimodal road.

For each destination (NUTS3 region), the total transport prices for unimodal road and rail/road transport from the Twin hub port locations are compared, and the cheapest option is selected. Each alternative option (intermodal terminal) is assigned a colour. The market area of each inland terminal in the Twin hub case regions is then highlighted in a map. These visualisations make it possible to see how large the market area of each intermodal terminal is (see Appendix 3). As a further step, the container flows data are used to show the amount of containers that belong to the market area of each intermodal terminal. In the Euro terminal model the flows to the market area are assigned in an all-or-nothing approach. Moreover, using weighted transport distances in pre- and end-haulage would likely give more reliable results regarding the best terminal location to visit.

Based on the results of the flow analysis (Chapters 5 and 7) and also the prevailing opinions of the rail operators regarding promising Twin hub routes when this analysis started, two hinterland cases have been elaborated: the Slaskie (Poland) spoke and the Basel/Vorarlberg (Switzerland/Austria) spoke. It was found that for the Slaskie spoke the terminal Sosnowiec would be most promising terminal and for the Basel/Vorarlberg spoke the Wheil am Rhein terminal.

A more detailed description of the Euro terminal model and its results can be found in Appendix 3.

7 Feasibility of the Twin hub pilot network: from flows to costs

(E. Kreutzberger and R. Konings)

The feasibility of the Twin hub pilot network is investigated by carrying out the following steps:

- Analyse the size of flows and trainloads in the different segments of the network (Section 7.1);
- Design the train operations (Section 7.2);
- Understand the rail market prices reported by the rail operators in the pilot to the project by calculating them on the basis of the train operations in Section 7.2 (Section 7.3);
- Calculate the door-to-door costs of intermodal rail transport per transport relation (Section 7.4), incorporating the rail market prices reported to the project by the rail operators in the pilot;
- Calculate the door-to-door costs of reference transport chains which consist of unimodal road transport, or of road transport, shortsea and rail transport (Section 7.4);
- Compare the costs per load unit of all-rail chains with reference mode chains (Section 7.4) to analyse the cost-competitiveness of all-rail chains.

7.1 Size of flows and trainloads

The O/D-flows analysed in Chapter 5 lead, when assigned to single train services, to the theoretical values shown in Figure 7.1a (pilot network with the UK train visiting neither Dourges nor Antwerp) and 7.1b (pilot network with the UK train visiting Dourges). The theoretical transport volume of a train service is the annual flow size divided by the number of weeks per year and the service frequency per week.

A train has a capacity of 88 or 102 TEUs per train (the train's length then is 600m or 700m respectively). If the theoretical trainloads shown in Figures 7.1 are smaller than the capacity, this indicates underutilization and relative high train costs per load unit. If the theoretical trainloads are larger the train capacity,

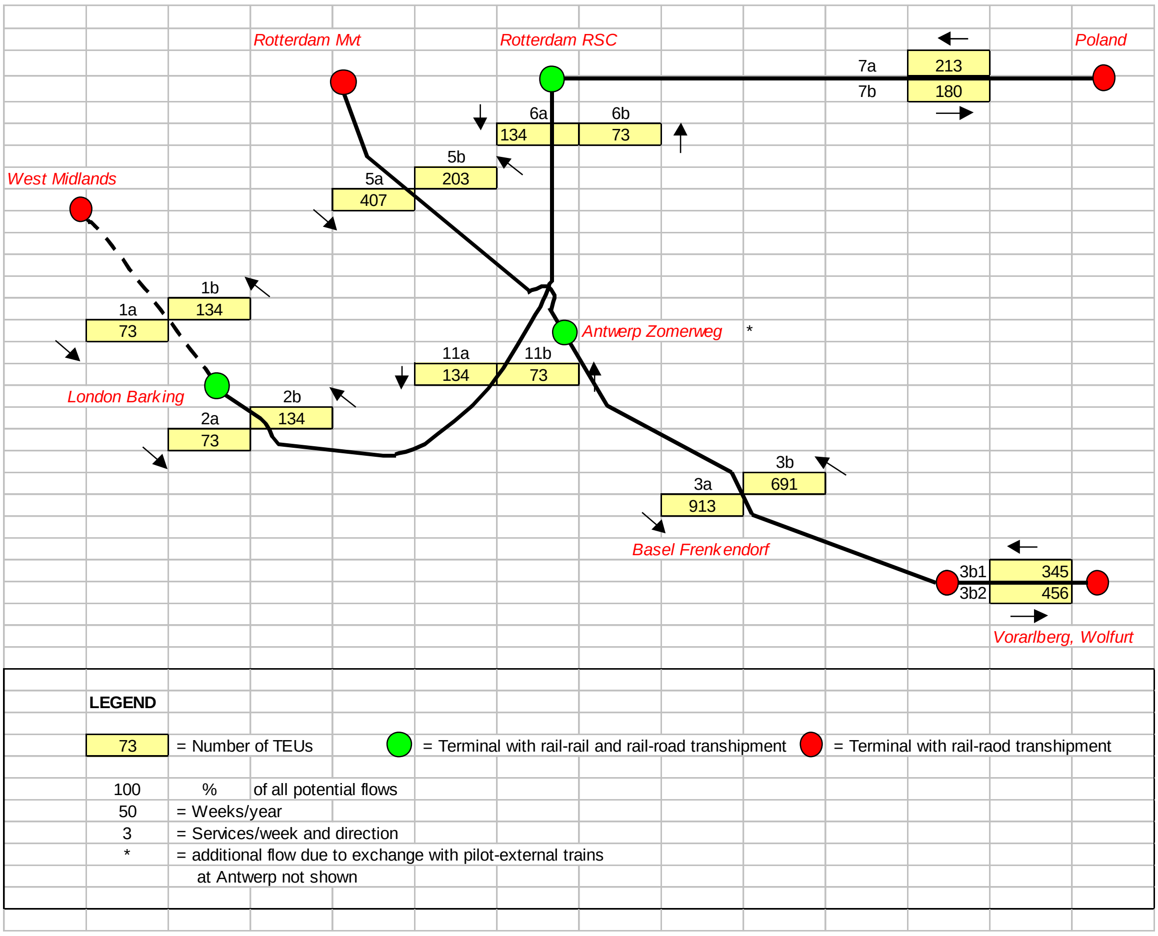
- the trainload will be the maximal one leading to relative low train costs per load unit;
- the service frequency being the intended or a higher one;
- and the residual flows not filling the train on a reasonable level being moved by other modes than train.

The theoretical transport volumes per train service in Figure 7.1:

- on the one side represent maximal ones as they are derived from the potential flows. The modal shift analysis will finish after the launching of this report. As a substitute this report carries out a sensitivity analysis, pointing out the consequences for trainloads and train costs per load unit, if only 50%, 40%, 30% or 20% of the potential rail flows really would choose for rail (Figures 7.2);
- on the other side represent minimal ones, as
  - freight flows in general are growing rapidly;
  - regional flows (like between Basel and Vorarlberg) are not incorporated;

- the effects of additional future rail services attached to the pilot network (like additional Poland trains) are not included.

Figure 7.1a Theoretical transport volumes per train service in the Twin hub pilot network if the UK train has no stop at Antwerp or Dourges (number of TEUs in 2010)



The dotted lines in Figures 7.1 represent train connections not belonging to the pilot network. The pilot network does or can benefit from its flows. In the UK this is considered to always be the case, as the UK flows to the west of London Barking do not depend on any additional action of the pilot train. For the French flows the additional flows will only emerge, if the UK-train stops at Dourges.

The transport volumes per service in Figure 7.1a show that without the UK train stopping and exchanging load units at Antwerp or Dourges, there is hardly a business case. The eastbound flows of West Midlands are 73 TEUs, the westbound ones 134 TEUs. If all load units went by train this volume is sufficient, otherwise it is likely to be too small.

In order to increase the size of trainloads Russell will let its pilot train London-Rotterdam stop at Dourges (Figure 7.1b). There UK-France, France-Rotterdam

Poland and France-Poland enter or leave the UK train. They represent a very positive impulse for the trainloads.

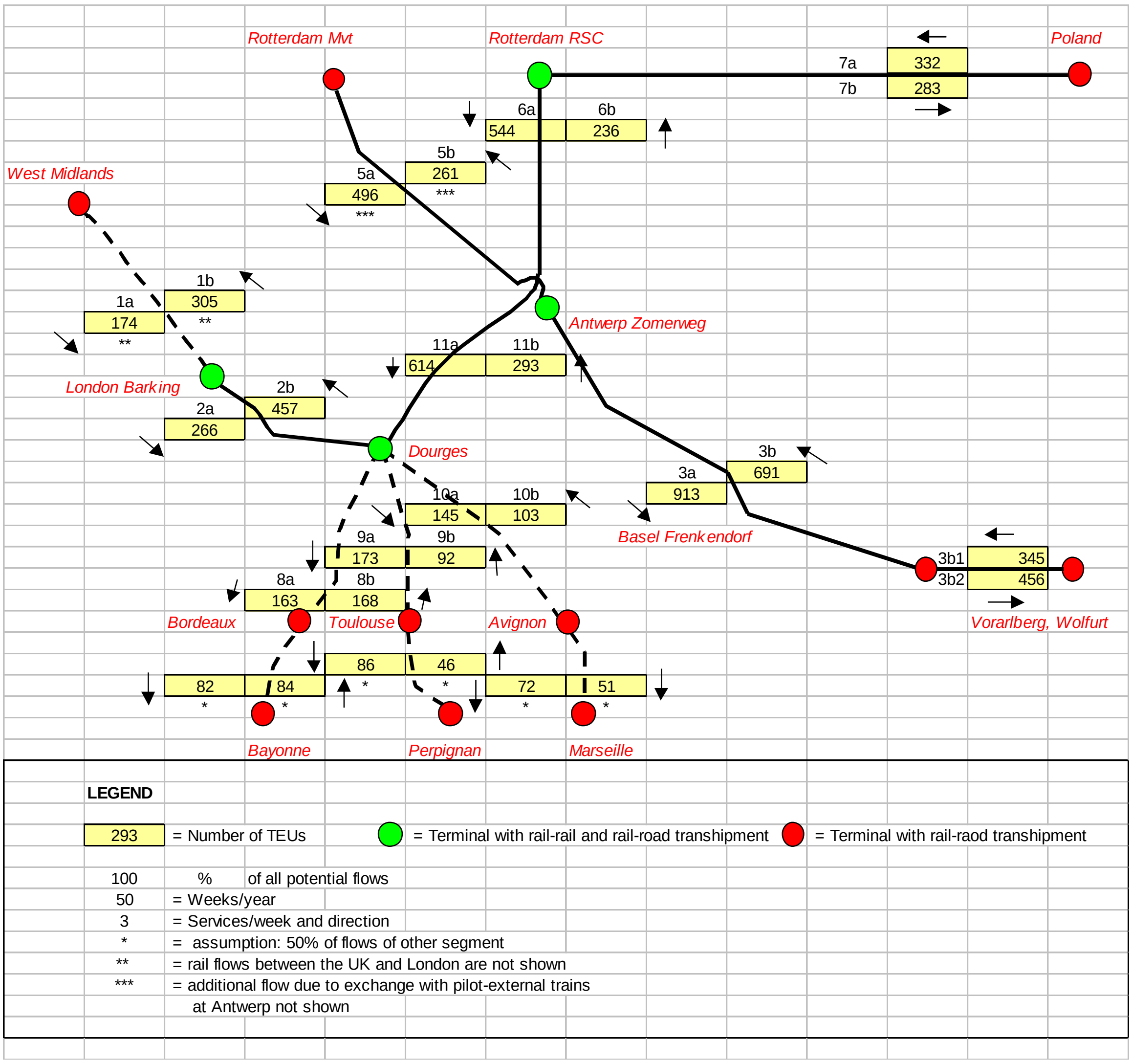
Figure 7.1b shows the theoretical flows of the pilot network, if the UK train visits Dourges in order to exchange load units with French trains. The volumes include – only to mention the doubtful cases – the transport relations:

- West-Midlands - Rotterdam and West Midlands - Poland. We then assume the rail chain West Midlands - Rotterdam to have been made competitive with the competing road-short sea chain.
- West-Midlands – region Dourges;
- Region Dourges – Poland;

and exclude:

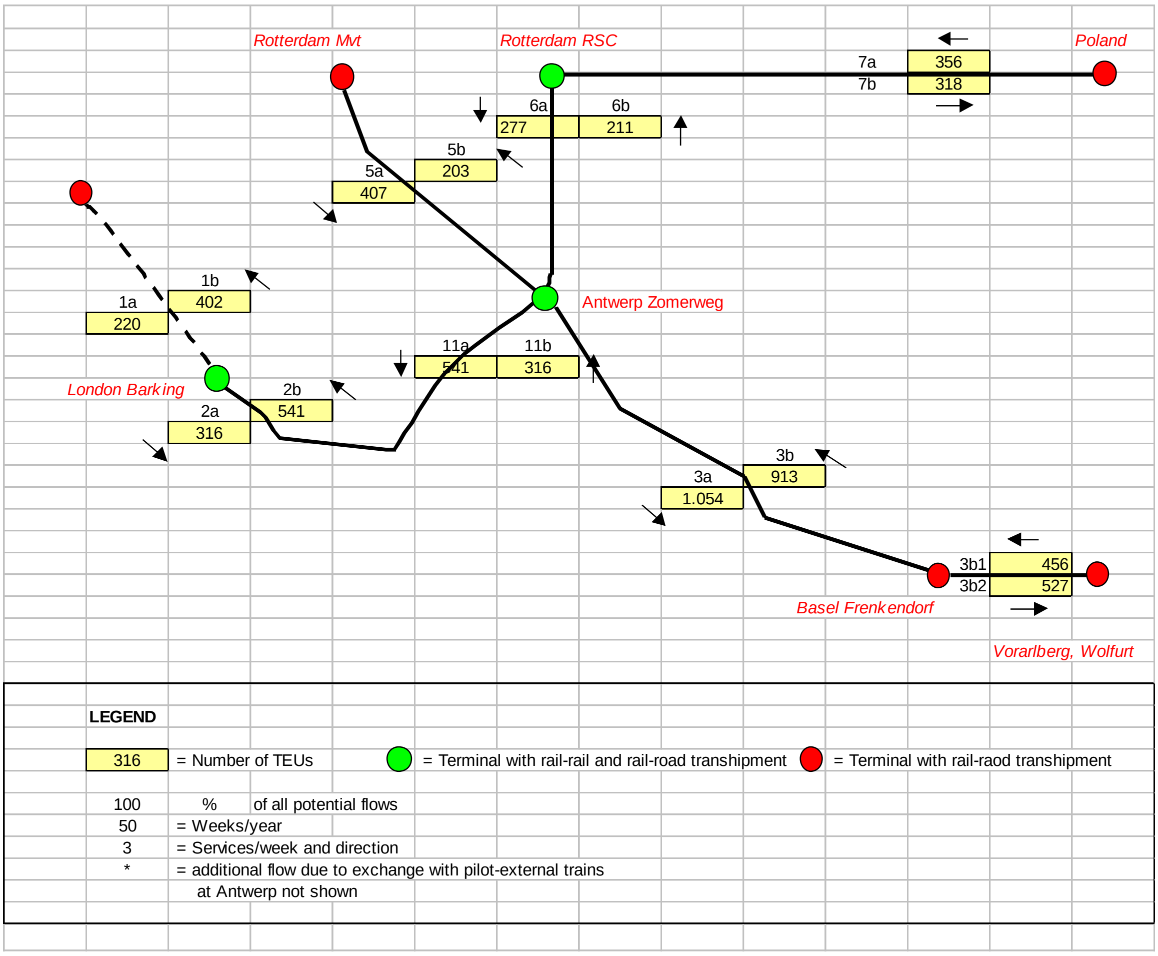
- London – region Dourges;
- London – Rotterdam;
- UK – Basel and further as the UK train does not visit Antwerp to exchange load units.

Figure 7.1b Theoretical transport volumes per train service in the Twin hub pilot network if the UK train visits Dourges (number of TEUs in 2010)



From the Twin hub network perspective it is of interest to compare the size of the pilot network with the former design of the pilot network, in which the UK train visits Antwerp instead of Dourges (Figure 7.1c). The trainloads on the UK train are slightly larger or smaller, dependent on the segment and direction. The differences between

Figure 7.1c Theoretical trainloads in the Twin hub pilot network if the UK train visits Antwerp (number of TEUs in 2010)



the segments are smaller. The potential size of trainloads is larger on the other two spokes (Poland and Switzerland/Austria). On the basis of this analysis the main difference between both networks (Figure 7.1b and c) is that in the first network the size of the trainload largely depends on the cooperation with non-pilot trains, as the Twin hub cooperation largely takes place on this level. In the former pilot network concept the train filling was mainly a result of pilot trains mutually exchanging load units. Whether this difference also applies in practice, depends on the concrete customers each rail operator has for its train and their geographical orientation.

The results are shown in:

- Figure 7.2a, assuming 50% of the potential flows shown in Figure 7.1b to go by train. At this level and at that of 40% all spokes have full trainloads;

- Figure 7.2b, assuming 30% of the potential flows shown in Figure 7.1b to go by train. The UK-Poland connection more or less still has full trainloads, while the trainloads on the UK spoke in the eastbound direction are slightly smaller than the train capacity. The loading degrees nevertheless still are excellent;
- Figure 7.2c, assuming 20% of the potential flows shown in Figure 7.1b to go by train. Now the trainloads of numerous rail segments of the pilot network are smaller than full trainloads. The competitiveness of train services in the pilot network is not any more evident. Anticipating on the results of the modal shift analysis, this level is unlikely to be achieved, meaning that the rail services, as far as the size of trainloads is concerned, have a good chance of being economically feasible.

Figure 7.2a Theoretical trainloads in the pilot network if 50% of all potential flows go by train (frequency = 3 services per week and direction)

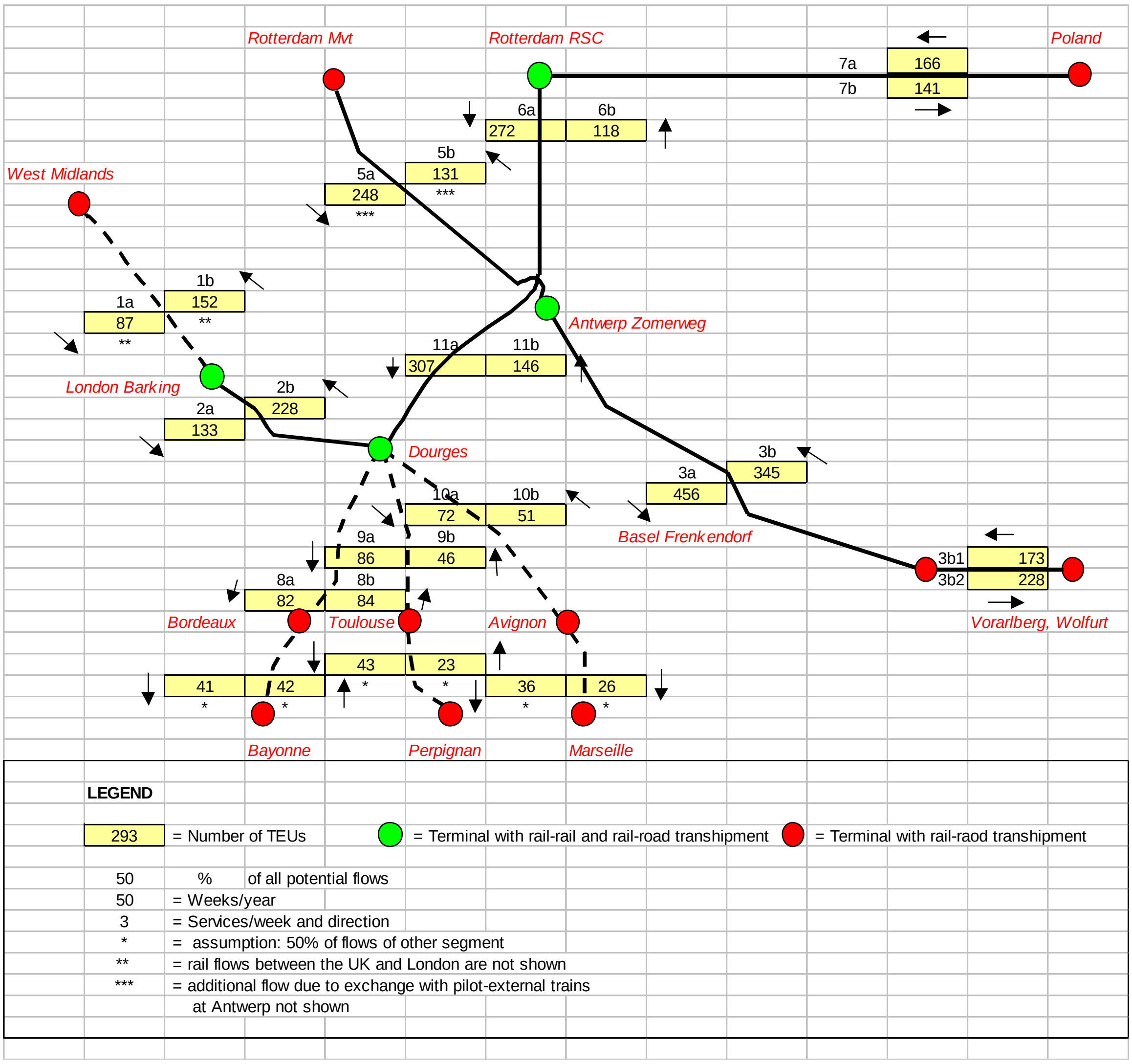
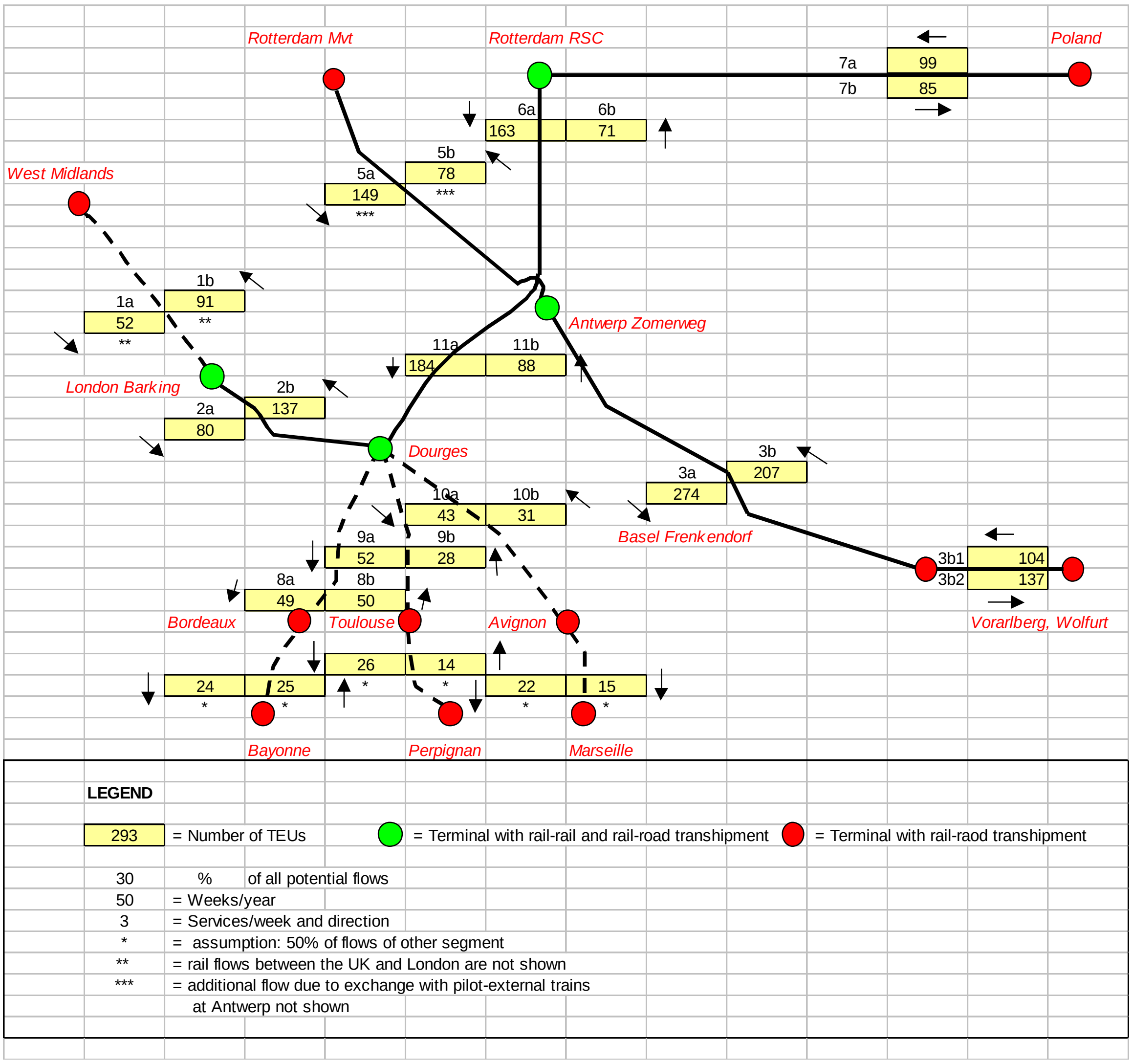


Figure 7.2b Theoretical trainloads in the pilot network if 30% of the potential flows go by train (frequency = 3 services per week and direction)



7.2 Design of operations, general features

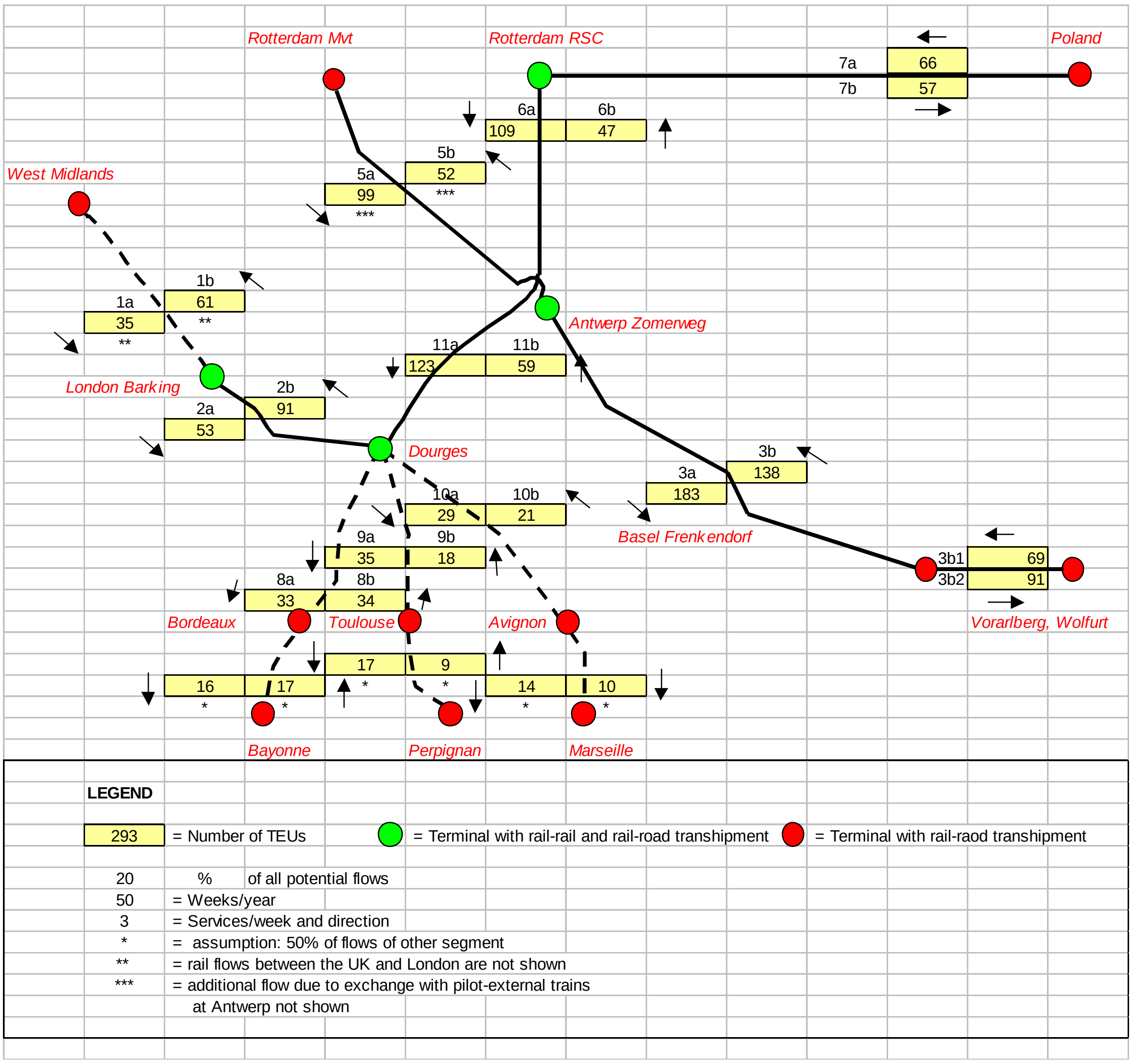
The following sections give an overview of the input used to analyse the feasibility of door-to-door rail services in the Twin hub pilot network.

7.2.1 Types and number of load units in a full trainload

A trainload can consist of 20', 30', 40' or 45'containers, their continental equivalents (= small to large swap bodies), optionally also semi-trailers. Many trains have mixed trainloads, expressible in the TEU-factor[14]. If a trainload consists of only 30'containers or carries just as much 20' as 40'containers, the TEU-factor is 1,5. The current TEU-factor of many trainloads is between 1,6 and 1,7, meaning that more large than small containers are used. A train with a wagon length of 600m and only one type of load units on board has – also dependent on the type of wagons used – a capacity of:

[14] A 20'container being one TEU.

Figure 7.2c Theoretical trainloads in the pilot network if 20% of the potential flows go by train (frequency = 3 services per week and direction)



20’ containers: up to 88 units; 40’ containers: up to 44 units; 45’ containers: up to 40 units.
For heavy goods, e.g. chemicals, weight rather than volume is the relevant capacity indicator, meaning that also smaller load units are competitive. In the chemical sector 20’ containers or their continental equivalents are widespread.

7.2.2 On the links

The link operations consist of all activities **between** exchange nodes, like between a begin terminal and a hub or between a hub and an end terminal, or between two hubs. The link time includes non-exchange-related waiting times, like at boarders or waiting on passenger trains etc. The average speed on links is high for long distances overnight (day A/B-services), like 80km/h and lower for longer distances. Day A/C-services is western Europe often have an average link speed of 40km/h, day A/D-services of 30km/h.[15]

7.2.3 Economical roundtrip times and night-jump operations

Wagons

One of the aims of well-designed train timetables is to provide train departure and arrival times which the customer can easily understand. Ideally the departure times on each departure day are (about) the same, and the arrival times on arrival days too. We call the corresponding roundtrip (time)s ***periodical roundtrip (time)s***. The operational roundtrip time consists of the time for driving back and forth, handling at nodes and waiting (e.g. at boarders of for passenger trains to pass). The periodical roundtrip time is the same plus the time needed to achieve periodical departure (or arrival) times. It is equal to the smallest multiple of 24 hours above the operational roundtrip time, like 24, 48 or 72 hours, dependent on the involved distance. If the operational roundtrip time is like 20 (or 40) hours, the economical roundtrip time is 24 (or 48 respectively) hours. The difference is non-productive waiting time with only one function, which serves to organise the desired departure and arrival times.

The periodical roundtrip time is the relevant time to us for the calculation of train costs.

A special case of the periodical roundtrip time is one serving so-called night-jump operations. Many freight trains move through the network during the night, departing in the late afternoon to early night and arriving in the late night to early morning. The departure and arrival times characterise the so-called night-jump operation. Night-jump operations provide **two benefits**, one dealing with infrastructure, the other with customers. At night the freight train has no or only a few conflicts with passenger trains using the same track. There is less waiting on passenger trains to pass, the average link speed is higher. The second benefit is that for customers applying the 8 hours economy. Night-jump departure and arrival times allow a load unit entering the production on the same day a train arrives and entering the train soon after a production day.

The periodical roundtrip time of night-jump train services is equal to the smallest multiple of 48 hours above the operational roundtrip time, like 48, 96 or 144 hours, dependent on the involved distance. If the operational roundtrip time is like 30 (or 70) hours, the economical roundtrip time is 48 (or 96 respectively) hours. The difference is non-productive waiting time with only one function, which is to organise the desired departure and arrival times.

Night-jump departure and arrival times are of special importance at inland terminals. At seaports, in particular at terminals for maritime flows at large ones like Rotterdam and Antwerp, which tend to operate 24 hours a day, night-jump departure and arrival times have little meaning.

The roundtrip for a connection between a seaport (no night-jump times) and an inland terminals (night-jump arrival and departure times) is a multiple of 24 hours, dependent on the distance.

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[15] The applied speed function resembling such speed features is described in the framework of the Rail cost model (Appendix 6).

The costs calculations of pilot trains are based on this approach.

Locomotives
Locomotives (and drivers) are much more costly than wagons. Therefore the challenge is to let them have shorter roundtrip times than the wagons. Ideally the locomotive, after having dropped a wagon set at a begin-and-end terminal for unloading, picks up a loaded wagon set as soon as possible for the retour journey or for triangle journeys. At large seaports, where night-jump departure and arrival times play a relative small role and transport volumes are relative large, a quick assignment to a new traction task is – functionally speaking – relative easy to carry out. At inland terminals, where night-jump arrival and departure times are appreciated and the transport volumes are smaller, a quick assignment is more challenging. Often the locomotive will wait until the wagon set it arrived with is unloaded and loaded again.
Organisationally speaking, the condition to accelerate the locomotive roundtrips is to have sufficient transport mass. Such is present either for the national incumbent railway firms (e.g. DB Schenker, SNCF fret) or for new firms having specialised in traction. For smaller intermodal rail operators carrying out own traction and using locomotives efficiently is rather contradictive. They need to tender the traction to specialised firms. The offered prices are accounted as traction costs per kilometre.

The traction providers, as far as their operational scale is concerned, can offer attractive traction prices. Whether they can and will, depends on their portfolio (are there enough jobs, also in the crisis, for the locomotives they have invested into?) and more in general on the balance between traction supply and demand.

In the pilot Russell and IMS Belgium tender traction. They and other firms depend on external traction, currently witness high traction prices. ERS has two units, one being an intermodal rail operator taking the commercial risk to run a train and selling its capacity, the other providing traction to the rail operator. The first will aim at being beneficial for the second unit, but of course also faces the question of finding enough employment for its locomotives and drivers.

Consequences for cost modelling
The described features in wagon and traction land play a role for the modelling of costs of pilot train operations. The calculation of wagon costs is solely based on periodical roundtrip times being a multiple of 24 hours. For traction a combination of such approach and of a traction price per kilometre is applied.

7.2.4 Exchange node times

The crane cycle to tranship a container or swap body to or from a train takes several minutes, in practice leading to a terminal transhipment capacity of about 30 load units per crane and per hour. Given a terminal having up to 3 cranes (or an equivalent number of reach stackers) and several trains being handled simultaneously, we assume the unloading and loading of a train to take 6 hours at an inland terminal, unless the operator advocates shorter times. At the deep-sea ports, the train handling roughly takes twice as long, namely 12 hours, given the optimisation priority at deep-sea terminals given to the seaside of operations above the landside.
At terminals functioning as a hub, a shorter time is needed. For simultaneous hub exchange we nevertheless assume the dwell time to be 5 hours, largely consisting of sufficient buffer time to avoid trains missing the exchange. For sequential exchange

the hub dwell time of a train can be shorter, like 2 hours per visit. In all cases 1 hour is added for local diesel locomotives moving the wagons to and from the terminals and for changing locomotives.

The locomotive partly waits at the terminal during handling (as at the hubs) or is assigned to new tasks after having arrived at the begin-and-end terminal and having dismissed its wagons to there.

7.2.5 Number of wagon sets

Certain combinations of service frequency and roundtrip time require more the one wagon set to connect the envisaged regions. This can easily be demonstrated by some examples. Of the periodical roundtrip time of a wagon set is 48 hours, the maximal number of complete roundtrips per week is 3. This allows providing a frequency of 3 services per week and direction. If the periodical roundtrip time is 72 hours, the maximal number of complete roundtrips per week is 2. With only 1 wagons set one cannot provide a frequency of 3 services per week and direction. The level of service requires two wagon sets. One of these wagon sets is well utilised (namely 6 of 7 days per week), the other badly (namely 3 of 7 days). With no additional work, this leads to relative low costs for the first wagon set en relative high ones for the second wagon set. The final wagon price lies in between the two.
For locomotives a similar mechanism may apply if things are badly organised. If the firm is large or if a large scale traction provider is asked to carry out the traction, the locomotives can be used more efficiently, meaning that they pull the described or other wagons in order to be at work most of the time.

7.3 Train prices and costs, approach

The train costs per load unit are calculated on the basis of the market prices of train services as reported by the rail operators in the pilot. These prices are compared with the output of the rail cost model RACOM (Kreutzberger, 2013; see Appendix 5). In general the market prices lie above the modelled costs, despite the fact that:

- the modelled costs include a surplus of 20% representing overhead, taxes and profit. As far as taking account of such cost ingredients, the modelled costs are comparable with market prices;
- the cost modelling does not include optimisations in the field of improved locomotive assignment to multiple (also pilot external) train services.

The difference between reported market prices and modelled costs ranges between 1,3 and 4,5 euro per traction-km (hence per train-km), the latter being an exception and referring to the services in the south-eastern corridor.

7.3.1 UK spoke

Company profile and market strategies of Russell

Russell:

- is a logistic specialist, operating a network of warehouses in the UK;
- is a road transport company running own trucks running in the UK;

- owns a number of intermodal rail-road terminals in the UK, including London Barking. This terminal is the one of the two British public terminals only that can receive non-UK wagons;
- initiates or uses trains running between the terminals of its warehouse locations. There are intermodal rail connections between London Barking on the one side and Cardiff, Manchester, Daventry and Scotland, Wakefield and a number of seaports on the other side;[16]
- is the forwarder of its own transport needs.

Russell aims at organising more work for its London terminal, and is interested in general business opportunities as establishing rail connections to new customers in France and Poland. His Twin hub train (= UK-spoke) serves this aim connecting London with the hubs Dourges and Rotterdam where they exchange load units with other trains.

Types of load units and wagons

On its Rotterdam-London spoke Russell intends to move continental goods using large load units, namely 45' containers on so-called megafrets. A megafret is a 90' long double wagon, suitable for the non-UK rail network. In the UK it can run up to the terminal London Barking using the high-speed track.[17] A 600m long train has, according to Russell, a capacity of 32 45'containers on 16 megafrets.

Roundtrip in the pilot

The train distance is 530km (Figure 7.3). The link time per roundtrip is (5,5+5,5+5+5=)[18] 21 hours. Using the Chunnel against affordable fees and the high-speed track in the UK leads to departure and arrival times in London which imply a dwell time of about 15 hours[19] at the London terminal. Table 7.1 shows that a roundtrip of 48 hours is not possible (not enough time in Rotterdam) and a roundtrip of 72 hours implies rather long time reserves per roundtrip (indicated by the dwell time of 26 hours in Rotterdam).[20]

Number of wagon sets

The roundtrip time of 72 hours in combination with the frequency of 3 services a week requires 2 wagon sets. The first has 2 roundtrips a week, which is well utilised, the second only 1, which is badly utilised.

Train market prices

The market price of a train roundtrip between London Barking and Rotterdam RSC at the frequency level of 3 services per week and including the Chunnel fees is reported to be 32.600 euro. That is roughly 16.300 euro per service. In addition, local trains cost 1.100 euro.

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16 These trains are operated by DB Schenker, Freightliner or Cobelfret.

17 A special feature on this pilot connection is the Chunnel connecting Dollands Moor/Dover with Calais-Frethun, and its attachment to the UK rail network. Between the Chunnel and the terminal London Barking trains with UK wagons can use the old track or the high-speed track. Trains with non-UK wagons can only use the high-speed track. The old track takes hours longer than the high-speed track. For non-UK wagons London Barking is the only UK terminal option. Russell intends to use the high-speed track.

18 5,5 hours includes the change of locomotives on the French side of the Chunnel.

19 Between the early night arrival and early morning departure.

20 In the 2013 pilot network with the UK train only running to Antwerp the situation would not have been much better.

Figure 7.3 The train roundtrip on the UK-spoke

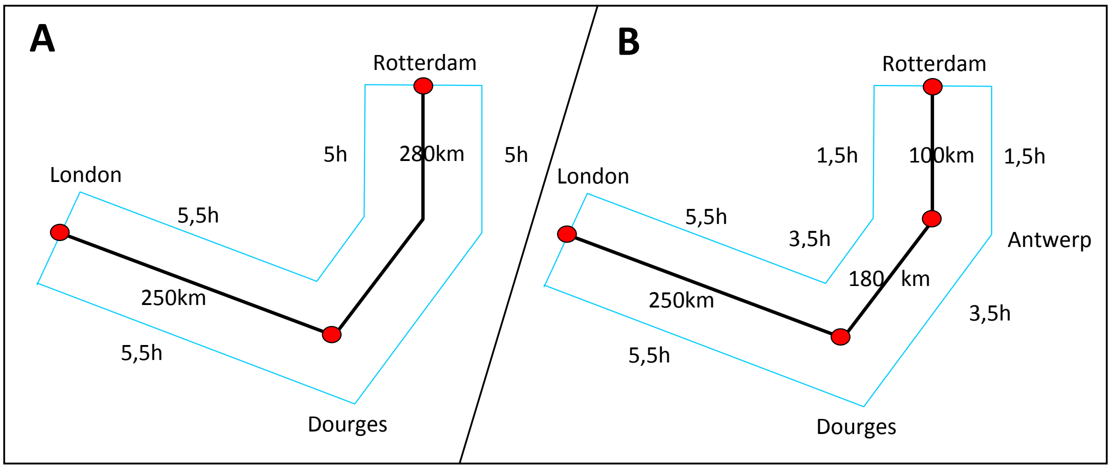


Table 7.1 "Alternative" roundtrips for the UK train
(Bold italic characters = input)

	Service	Roundtrip	Service	Roundtrip
Total	***24***	***48***	***36***	***72***
London	***7,5***	***15***	***7,5***	***15***
Links	***10,5***	***21***	***10,5***	***21***
Dourges	5	10	5	10
Rdam	1	2	13	26

Without the Chunnel fee of 3.780 euro per service the train costs are 12.520 euro per service. Between London RSC and West Midlands the market price is about 22 euro per train-km.

Understanding the market price. Train costs according to RACOM

The market prices are higher than the train costs calculated in RACOM. The difference is equivalent to 1,9 euro per train-km (Table 7.2). Including this difference leads to train costs of 12.500 euro, hence the market price.

The first column in Table 7.2 presents the train costs on this price level, if one train has 2 roundtrips a week and the other 1 roundtrip a week. The average costs are of trunk trains are 23,5 euro per train-km.

Table 7.2 Understanding the market price: train costs (euro) between London Barking and Rotterdam RSC

		530	530
		Lon - Rdam RSC	Lon - Rdam RSC
Overhead %		20	20
Extra tractie-kosten (euro/km)		1,9	1,9
Factor time labour costs		1,0	1,0
Frequency = number of system RTs per week	*	**3**	**4**
Frequency = number of RTs 1st train per week		**2**	**2**
Frequency = number of RTs 2nd train per week		**1**	**2**
Frequency = number of RTs 3rd train per week			
Number of RTs per year		156	156
Distance per HaRT	km	***530***	***530***
Speed	km/h	80	80
Operational driving time per HaRT	hours	10,5	10,5
Time 2 half BE terminals per HaRT	hours	*9*	*9*
Number of hubs		*1*	*1*
If hub, dwell time per hub	hours	*5*	*5*
Time hub (or other intermediate nodes)	hours	5	5
Total operational HaRT time	hours	24,5	24,5
Total operational RT time	hours	49	49
Day-periodical RT time	hours	72	72
Day-periodical HaRT time	hours	36	36
Week-periodical RT time	hours	56	56
Week-periodical HaRT time	hours	28	28
Fictive maximal number of RTs per week		2,3	2,3
Real (= off-rounded) operationally maximal number of RTs per week		2,0	2,0
Number of train sets (fictive)		1,5	1,5
Number of train sets (real)		2	2
All train services per week of both trains in 1 direction (= F1*C1+F2*C2)			
Total including overhead		37.396	43.322
Local train		3.300	4.400
Total including overhead and local train		40.696	47.722
Of which traction costs (including proportion of overhead costs)		30.473	36.399
(Frequency weighted) Average costs of services of both trains			
Total including overhead		12.465	10.831
Local train		1.100	1.100
Total including overhead and local train		13.565	11.931
Trunk and local trains and tunnel fee (ETICA substracted)		17.345	15.711
Of which traction costs (including proportion of overhead costs)		10.158	9.100
(Frequency weighted) Average costs of RTs of both trains			
Total including overhead		24.930	21.661
Local train		2.200	2.200
Total including overhead and local train		27.130	23.861
Trunk and local trains and tunnel fee (ETICA substracted)		34.690	31.421
Of which traction costs (including proportion of overhead costs)		20.315	18.200
Average costs per trein-km			
Total including overhead		23,5	20,4
Local train		2,1	2,1
Total including overhead and local train		25,6	22,5
Total including overhead, local trains and tunnel fee (ETICA subtracted)		32,7	29,6
Of which traction costs (including proportion of overhead costs)		19,2	17,2

Improvement towards the pilot

If the frequency was 4 instead of 3 service a week, also the second wagon set have 2 roundtrips a week instead of only 1. This would reduce the average train costs by about 4 euro per train-km lower (second column of the Table 7.2). Such cost levels would also emerge for the frequencies of 2 or 6 services per week.

7.3.2 Poland spoke

Company profile and market strategies of ERS

European Rail Shuttle (ERS), initially founded by Maersk and other maritime companies to serve maritime hinterland flows by rail, has been taken over by the British rail operator Freightliner and is increasingly serving the continental rail market. Most of its trains run between Rotterdam and inland terminals on the continent. ERS already has one Poland train connecting Rotterdam with Poznan. ERS intends to serve the Polish market more intensely, preparing a number of new connections. Typically the flow sizes will only allow a low service frequency. Any measure to increase the flow sizes is welcome. Within the Twin hub network such measures could be the UK train delivering France-Poland and the Basel train delivering Antwerp-Poland load units.

Establishing a train connection between the UK and Poland by own trains or trains of cooperating firms will also connect the two rail network regions of the mother company. Currently Freightliner runs trains in the UK and in Poland without having any rail connections between the two regions.

Market strategies, and types of load units and wagons

The trains of ERS have a mix of continental and maritime load units, large and small load units, their average expressed by the TEU-factor 1,7. Part of their load units will be the 45’containers of Russell. These features also refer to the pilot train to Slaskie.

The UK train will also feed an existing train service of ERS, namely Rotterdam RSC – Poznan, allowing to increase the service frequency from 3 to 4 services a week.

Roundtrip

The train distance between Rotterdam RSC and the inland terminal Sosnowice in the region Slaskie is 1170km. RSC functions as begin-and-end terminal and hub. There are no other hubs or other exchange nodes between the two terminals. The sum of operational times leads to a periodical roundtrip time of 72 hours. This roundtrip includes a dwell time of 6 hours at Rotterdam RSC and of 12 hours at the Polish inland terminal. At the German-Polish boarder the trains change locomotives.

Number of wagon sets

The train service between Rotterdam RSC and Slaskie requires, given a roundtrip time of 72 hours and the frequency of 3 services per week and direction, 2 wagon sets. One of them has 2 roundtrips a week and is well used, the other only has 1 roundtrip a week.

Train market prices

The market price of a train operation between Rotterdam and Slaskie is reported to be 23.000 euro per service including local trains.[21]

Understanding the market price. Train costs according to RACOM

The market prices are higher than the train costs calculated in RACOM. The difference is equivalent to 3,9 euro per train-km (Table 7.3). Including this difference leads to train costs of 23.000 euro, hence the market price.

[21] 36.000 euro per roundtrip without local trains (HUSA, 2013)

Table 7.3 Understanding the market price: train costs (euro) between Rotterdam RSC and Slaskie

		1170
		RSC - Slaskie
Overhead %		20
Extra tractie-kosten (euro/km)		3,9
Factor time labour costs		1,4
Frequency = number of system RTs per week	*	**3,00**
Frequency = number of RTs 1st train per week		**2,00**
Frequency = number of RTs 2nd train per week		**1,00**
Frequency = number of RTs 3rd train per week		
Number of RTs per year		156
Distance per HaRT	km	***1170***
Speed	km/h	39
Operational driving time per HaRT	hours	29,9
Time 2 half BE terminals per HaRT	hours	***6***
Number of hubs		***0***
If hub, dwell time per hub	hours	***3,9***
Time hub (or other intermediate nodes)	hours	5
Total operational HaRT time	hours	40,9
Total operational RT time	hours	82
Day-periodical RT time	hours	96
Day-periodical HaRT time	hours	48
Week-periodical RT time	hours	56
Week-periodical HaRT time	hours	28
Fictive maximal number of RTs per week		1,8
Real (= off-rounded) operationally maximal number of RTs per week		1,0
Number of train sets (fictive)		3,0
Number of train sets (real)		3
All train services per week of both trains in 1 direction (= F1*C1+F2*C2)		
Total including overhead		69.082
Local train		1.950
Total including overhead and local train		71.032
Of which traction costs (including proportion of overhead costs)		62.159
(Frequency weighted) Average costs of services of both trains		
Total including overhead		23.027
Local train		650
Total including overhead and local train		23.677
Of which traction costs (including proportion of overhead costs)		20.720
(Frequency weighted) Average costs of RTs of both trains		
Total including overhead		46.055
Local train		1.300
Total including overhead and local train		47.355
Of which traction costs (including proportion of overhead costs)		41.439
Average costs per trein-km		
Total including overhead		19,7
Local train		0,6
Total including overhead and local train		20,2
Of which traction costs (including proportion of overhead costs)		17,7

The operations employ two trains, one having 2 roundtrips a week, the other one 1 roundtrip a week. The average costs of trunk trains are 19,7 euro per train-km. This is a very competitive level, despite of the two wagon-sets and due to the relative long distance. The costs would be lower on the frequency levels of 2, 4 or 6 services per week, as each train then has 2 roundtrips a week.

7.3.3 Basel/Vorarlberg spoke

Company profile and market strategies of IMS Belgium

IMS Belgium together with IMS Switzerland and IMS Netherlands, all daughters of IMS Austria, are specialised in the transport of containers between Switzerland and Austria on the ones side and the "northern" seaports (mainly Hamburg and Bremerhaven) and the "western" seaports (mainly Rotterdam, but also Antwerp). IMS wants to:

1) intensify its services to the western ports. The price competition with the northern seaports (mainly Hamburg and Bremerhaven) is fierce. Higher rail prices to the
2) west are acceptable in return for saving money on the ocean. Containers on the western ports have shorter sailing times than to the northern ones.
3) strengthen its position in Antwerp. But the Antwerp flows of IMS are small;
4) find a growth path for Rotterdam flows. Currently, IMS runs several trains a week between Switzerland/Austria and Rotterdam. The trains are fully loaded. New customers force the operator to also run a short train; not attractive; new customers are likely to be refused.
5) consolidate the terminal visits in Rotterdam. Currently, each of the Rotterdam trains visits 2 to 3 rail terminals in Rotterdam per roundtrip. The situation is likely to become worse when Maasvlakte 2 opens end of 2014. Visiting only 1 terminal in Rotterdam can save a lot of time. Letting load units of a train also reach the other terminals is possible, if the train visits a hub first (the logic of Figure 6.3). The roundtrip time of a train is increased by visiting a hub and reduced by only visiting one rail terminal in the seaport, together reducing the roundtrip time.

The aims 3 and 4 are the most important ones for IMS being interested in the Twin hub project. Bundling the growth volumes of Rotterdam with the small volumes of Antwerp can fill a train that connects Basel with Antwerp and Rotterdam.[22] Loads from non-pilot trains will then have to contribute to filling the train between Antwerp and Rotterdam (see Section 3.2).
Visiting a hub between Basel and the seaports can also contribute to aim 5. However, such bundling could also be solved by the hub which IMS operates near Basel (terminal Reckingen).

Types of load units and wagons

IMS Belgium is mainly involved in maritime flows. Its customers use a variety of different load unit types, many of them being 40’containers.

Roundtrip and number of wagon sets

Current roundtrips of Basel - Rotterdam trains of IMS last at least 72 hours, if the train visits 2 rail terminals in Rotterdam, and at least 96 hours, if it visits 3 rail terminals in Rotterdam. Using this as orientation, the connection Basel - Antwerp - Rotterdam or Basel - Rotterdam - Antwerp could either last 72 hours or 96 hours (Table 7.4).

Table 7.4 Roundtrip options, their distance and time

	Rdam Mvt – Antwerp – Frenkendorf
Distance	870 km
Time roundtrip	72 – 96 hours

[22] This small volume in October 2013 made IMS Belgium start a new train service connecting Switzerland/Austria and Antwerp. Its frequency was 2 services per week and the trains were short. The service depended on the UK-spoke to be implemented by means of which the Basel train could also be loaded with Rotterdam load units. The UK-spoke however did not come on stream. After a customer dropping off and due to the delay of the implementation of other Twin hub connections, this service was stopped again in January 2014.

To carry out the service 3 times per week, two wagon sets are required. One will run twice a week, the other only once a week

Train market prices

The market price of a train operation between Rotterdam Maasvlakte / Antwerp and Basel (Frenkendorf) is reported to be 20.500 euro plus 1.300 euro for local trains, together 21.800 euro.

Understanding the market price. Train costs according to RACOM

The market prices are higher than the train costs calculated in RACOM. The difference is equivalent to 5,8 euro per train-km (Table 7.5). Including this difference leads to train costs of about 21.800 euro, hence the market price.

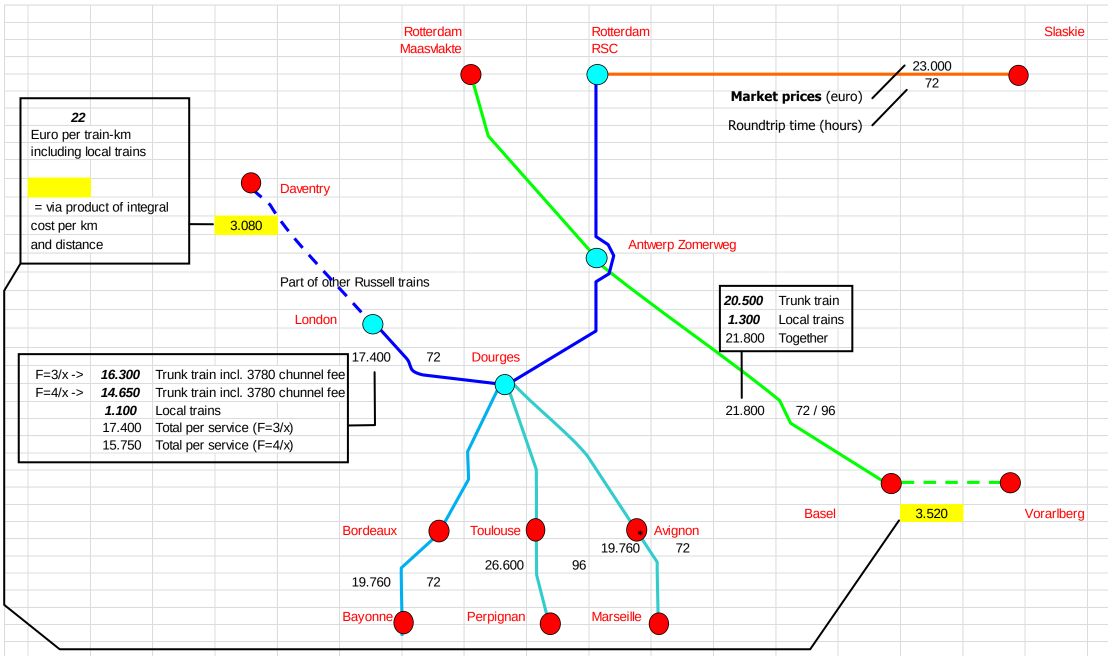
Table 7.5 Understanding the market price: train costs (euro) between Rotterdam Maasvlakte - Antwerp – Basel (Frenkendorf)

		A	B
		870	870
		Rdam - Antwerp - Basel	Rdam - Antwerp - Basel
Overhead %		20	20
Extra tractie-kosten (euro/km)		5,8	5,8
Factor time labour costs		1,4	1,4
Frequency = number of system RTs per week		3	3
Frequency = number of RTs 1st train per week		2	1
Frequency = number of RTs 2nd train per week		1	1
Frequency = number of RTs 3rd train per week			1
Number of RTs per year		156	156
Distance per HaRT	km	*870*	*870*
Speed	km/h	58	58
Operational driving time per HaRT	hours	14,9	14,9
Time 2 half BE terminals per HaRT	hours	*9*	*11*
Number of hubs		*1*	*1*
If hub, dwell time per hub	hours	*5*	*11*
Time hub (or other intermediate nodes)	hours	5	11
Total operational HaRT time	hours	28,9	36,9
Total operational RT time	hours	58	74
Day-periodical RT time	hours	72	96
Day-periodical HaRT time	hours	36	48
Week-periodical RT time	hours	56	56
Week-periodical HaRT time	hours	28	28
Fictive maximal number of RTs per week		2,3	1,8
Real (= off-rounded) operationally maximal number of RTs per week		2,0	1,0
Number of train sets (fictive)		1,5	3,0
Number of train sets (real)		2	3
All train services per week of both trains in 1 direction (= F1*C1+F2*C2)			
Total including overhead		61.603	73.891
Local train		3.900	3.900
Total including overhead and local train		65.503	77.791
Of which traction costs (including proportion of overhead costs)		54.680	77.791
(Frequency weighted) Average costs of services of both trains			
Total including overhead		20.534	24.630
Local train		1.300	1.300
Total including overhead and local train		21.834	25.930
Of which traction costs (including proportion of overhead costs)		18.227	21.169
(Frequency weighted) Average costs of RTs of both trains			
Total including overhead		41.069	49.261
Local train		2.600	2.600
Total including overhead and local train		43.669	51.861
Of which traction costs (including proportion of overhead costs)		36.453	42.338
Average costs per trein-km			
Total including overhead		23,6	28,3
Local train		1,5	1,5
Total including overhead and local train		25,1	29,8
Of which traction costs (including proportion of overhead costs)		21,0	24,3

Table 7.5 presents train costs shows for alternative roundtrips models (columns A and B) at this price level. Column A shows the costs if one train has 2 roundtrips a week[23] and the other train 1 roundtrip a week.[24] The average costs of trunk trains are 23,6 euro per train-km. In this model two roundtrips Basel-Antwerp-Rotterdam are allowed to last 96 hours and one 72 hours. With the present Rotterdam services as reference this should be manageable. If each roundtrip needs 96 hours, the costs per train-km move up to 28,3 euro, a rather non-competitive level. If on the other side the price level would drop (so that the artificial "difference" of 5,8 euro per train-km would decline), such service would move into the competitive range again.

Figure 7.4 summarises the input for train costs, namely the train prices presented in Section 7.3. Recapitulating, for the pilot trains the costs of other operations are the ones mentioned by the rail operators. For the non-pilot trains in the UK and Austria the train costs have been approached by kilometric train costs. For the non-pilot trains in France the train costs have been calculated in a similar way as the in calculations to understand the market prices of pilot trains.

Figure 7.4 Market prices on the different spokes of the Twin hub pilot



7.4 The cost competitiveness of rail connections

The following step is to analyse the competitiveness of the pilot rail services, in particular the cost competitiveness. Wherever of relevance, also the transport quality is taken along to draw conclusions about the total competitiveness of the pilot.

In the approach of this section a rail connection is considered to be cost competitive if the door-to-door costs per load unit of Twin hub operations are not higher than those

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23 The costs per train roundtrip are 18.900 euro.
24 The costs per train roundtrip are 23.800 euro.

of the reference mode. The rail part consists of the train prices presented in Section 7.3 plus the node exchange costs.

Most often the **reference mode** is unimodal road transport. In case of the UK-Poland connection, a PPH-train-train-PPH chain, the **reference chain** is truck-short sea-train-PPH, Rotterdam being the exchange node between Twin hub trains or – in the reference chain – between short sea and train.

The train costs per load unit are calculated by dividing the train costs by the number of load units. The latter depends on the size of involved flows and the types of load units involved, and is limited to the capacity of a 600m long train. These ingredients require further explanation.

- Size of involved flows. The potential flows identified in Section 7.1 are the starting point. It the framework of a sensitivity analysis the potential flows are varied, down to the level of 20% of the potential flows. The smaller the flows, the less cost-competitive the Twin hub operations may be. The sensitivity analysis anticipates on the results of the modal shift analysis.[25]
- Type of load units involved. These can be a small number of 45'containers or a larger number of 20' containers and their continental equivalents, just to mention the extremes. The type of load units influences the train costs per load unit, but – in most cases – not the truck costs per load unit, because most current truck types will carry only one load unit whatever the size is.[26]
- Maximal number of load units per train (100% of a 600m long train). Table 7.6 shows the numbers for different types of load units. Figures 7.5 and 7.6 illustrate these limits and the resulting trainload sizes.

Table 7.6 Maximal number of load units per train (600m length; given optimal wagon type)

Type of load unit	Maximal number of load units
45'	40
40'	44
1,7 TEU	51
1,5 TEU	60
20'	88

The train costs per load unit are derived from dividing the train costs of Figure 7.4 by the number of load units per train. For instance, 23.000 euro for the Poland train (Figure 7.4) divided by 51 load units (Figure 7.5) leads to about 450 euro per load unit (Figure 7.7).

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[25] In the modal shift analysis to be carried out after this report, the competitiveness is analysed in a more sophisticated way, using a Logit function instead of an all-or-nothing approach, and iterating flow sizes and costs per load unit.

[26] This reduces the scale advantages from 2,25 to 2,0 (in case of 35 x 45'containers) or 1,8 (in case of 32 x 45'containers).

Figure 7.5 Number of 1,7 TEU load units on the different segments of the pilot (given 100% of potential flows; train length = 600m)

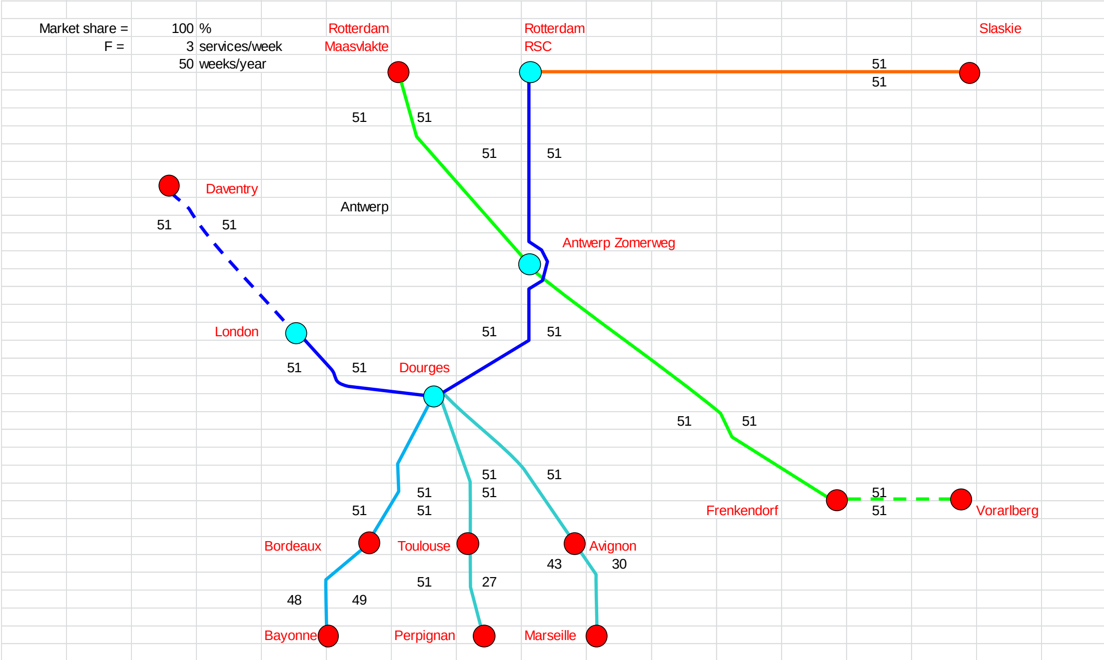


Figure 7.6 Number of 45' containers on the different segments of the pilot trains (given 100% of potential flows; train length = 600m)

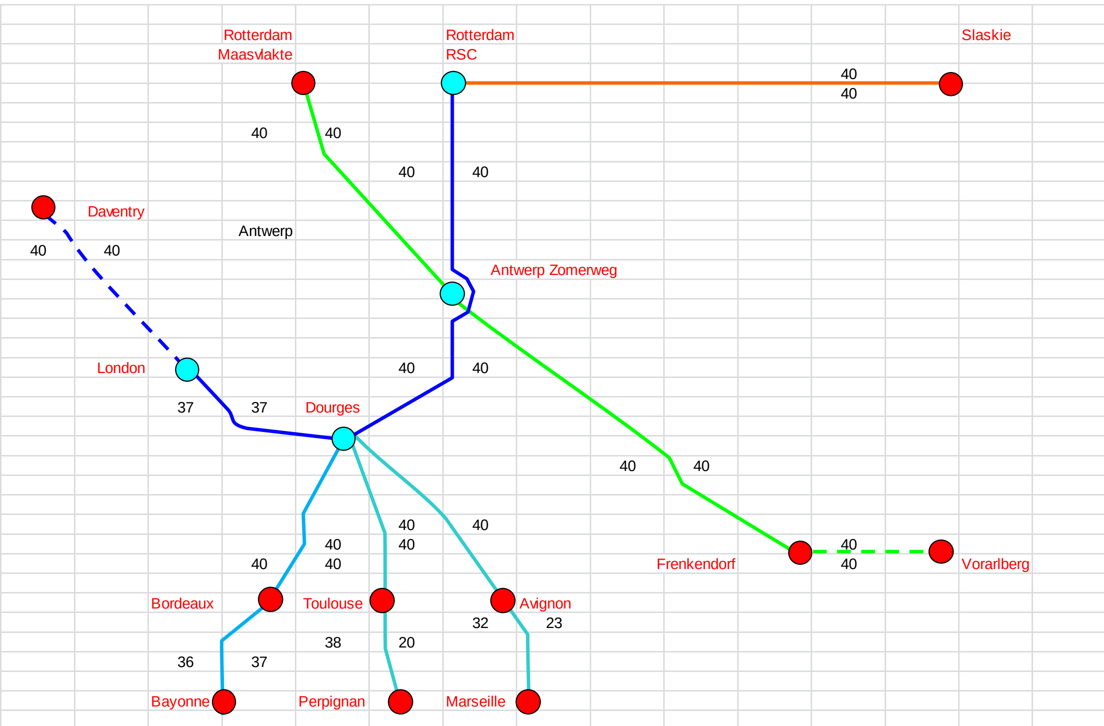
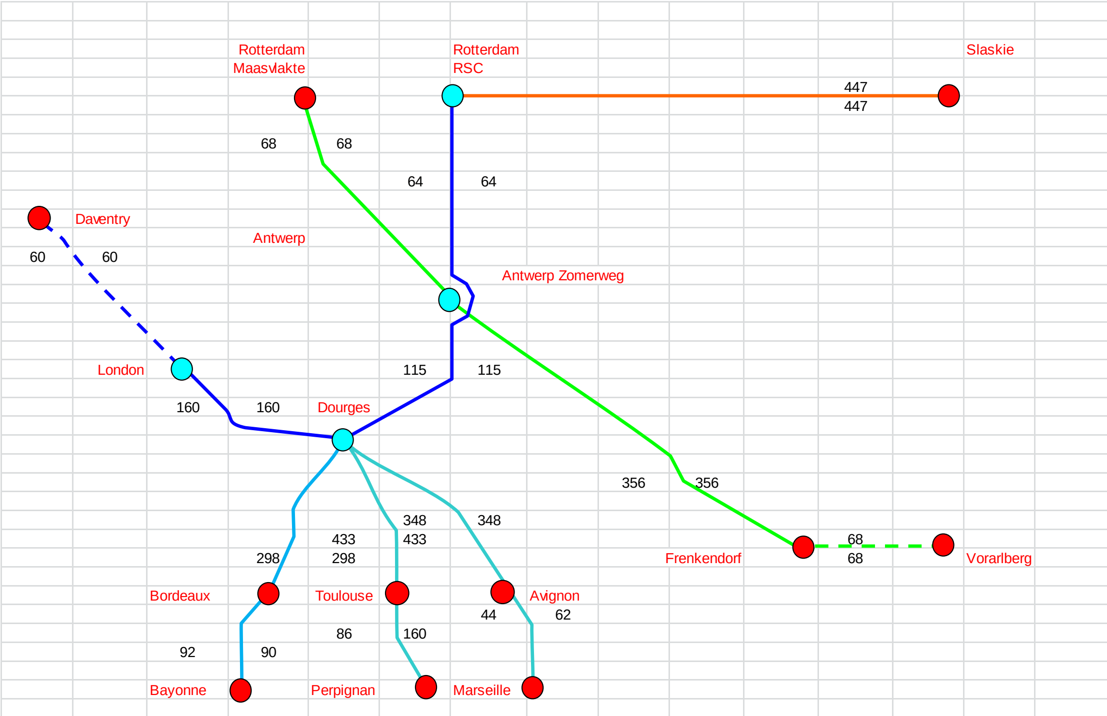


Figure 7.7 Costs of trunk and local trains per 1,7 TEU load unit (given 100% of potential flows; train length = 600m)



The door-to-door costs of the all-rail chains are calculated by adding the costs of other operations (pre- and post-haulage; node exchange) to the train costs per load unit of like those in Figure 7.7. For **1,7 TEU load units** the result is shown in Table 7.7.

The hub costs largely depend on the number of hubs a load unit visits (L = London, D = Dourges in France, RSC = Rail service centre Rotterdam, R = Reckingen in Switzerland). For the flows between Switzerland on the one side and Rotterdam Maasvlakte or Antwerp on the other side – these flows are maritime ones – the terminal and PPH costs in the seaport are assumed to be part of the maritime price and therefore are not mentioned separately (light blue fields in Table 7.7).

Table 7.8 shows the costs of the reference chains, with unimodal road or shortsea and train. A conclusion is that for the UK-Poland connection the all-rail costs are about 1300 euro per load unit (Table 7.7) and those of the reference chain 1400 (Table 7.8) meaning that at this flow level (100% of the potential flows go by train) the all-rail chain is cost competitive.

At other flow levels (with fewer load units than the potential) the all-rail chains may be less competitive. In general, the French and Swiss spokes are cost competitive at all envisaged flow levels (20% and more), while most UK flows require that at least 30% of the potential flows go by train (Table 7.9a). The only exception are westbound Poland-Daventry flows which are feasible already on the 20% level. It seems likely that such flow levels will be achieved. Formally, the modal shift analysis still has to conform this.

Table 7.7 Door-to-door costs of trains per 1,7 TEU load unit of all-rail chains (pilot and other trains) (100% of potential flows go by rail)

ALL RAIL

LU = 1,7 TEU
-> capacity train = 51 load units

From / to		PPH UK	Terminal UK	UK TRAIN: Trunk + local – Train costs on UK-train (market share = 100 %) eastbound	UK TRAIN: Trunk + local – Train costs on UK-train (market share = 100 %) westbound	PPH continent	Terminal continent	Hub	Hub	CONTINENTAL TRAIN: Trunk + local – Train costs on other train (market share = 100 %) eastbound	CONTINENTAL TRAIN: Trunk + local – Train costs on other train (market share = 100 %) westbound	Terminal continent	PPH continent	eastbound TOTAL forth	westbound TOTAL back
Daventry	Rdam RSC	210	28,8	398	398			L+D	70			40	113	860	860
	Slaskie	210	28,8	398	398			L+RSC	70	447	447	26	123	1.303	1.303
	Bordeaux	210	28,8	219	219			L+D	40	298	298	40	140	976	976
	Bayonne	210	28,8	219	219			L+D	40	390	388	40	140	1.069	1.066
	Toulouse	210	28,8	219	219			L+D	40	433	433	40	140	1.111	1.111
	Perpignan	210	28,8	219	219			L+D	40	518	593	40	140	1.197	1.271
	Avignon	210	28,8	219	219			L+D	40	348	348	40	140	1.026	1.026
	Marseille	210	28,8	219	219			L+D	40	392	410	40	140	1.070	1.088
London	Bordeaux	180	30,0	160	160			D	40	298	298	40	140	888	888
	Bayonne	180	30,0	160	160			D	40	390	388	40	140	980	977
	Toulouse	180	30,0	160	160			D	40	433	433	40	140	1.022	1.022
	Perpignan	180	30,0	160	160			D	40	518	593	40	140	1.108	1.183
	Avignon	180	30,0	160	160			D	40	348	348	40	140	938	938
	Marseille	180	30,0	160	160			D	40	392	410	40	140	981	999
Antwerp	Frenkendorf								0	424	424	30	140	594	594
	Vorarlberg							R	30	492	492	30	140	692	692
Rdam Mv	Frenkendorf								40	424	424	30	140	634	634
	Vorarlberg							R	30	492	492	30	123	675	675
Rdam RSC	Slaskie					113	40	RSC	40	447	447	26	123	788	788
Bordeaux	Slaskie					140	40	D+RSC	80	447	447	26	123	856	856
Bayonne	Slaskie					140	40	D+RSC	80	447	447	26	123	856	856
Toulouse	Slaskie					140	40	D+RSC	80	447	447	26	123	856	856
Perpignan	Slaskie					140	40	D+RSC	80	447	447	26	123	856	856
Avignon	Slaskie					140	40	D+RSC	80	447	447	26	123	856	856
Marseille	Slaskie					140	40	D+RSC	80	447	447	26	123	856	856

Table 7.8 Door-to-door costs of reference mode chains
(UK-Rotterdam and UK-Poland = truck-short sea-train-PPH chains;
Other chains are all-road chains)

REFERENCE MODE

From / to	Used seaport continent	UK ROAD: Truck UK euro	and SHORTSEA: Quay UK euro (Included in C)	Shortsea euro	Quay Rdam euro (Included in C)	Transfer costs Rdam euro	RSC euro	Intermediate data and calculations: Distance truck UK	Distance truck Continent	Distance truck total km	euro/km	euro		ALL ROAD: Truck UK and continent euro	and TRAIN (Poland): Rail continent eastbound euro	Rail continent westbound euro	Terminal Slaskie euro	PPH Slaskie euro	All road	Road and shortsea	Rroad, short sea and rail eastbound	westbound
Daventry	Rdam RSC	510	0	250	0					25	4,5	113	None ->					113		873		
	Slaskie	510	0	250	0	25	40						Train ->		447	447	26	123			1421	1421
	Bordeaux							323	846	1169	1,1	1286		1479					1479			
	Bayonne							323	1031	1354	1,1	1489		1713					1713			
	Toulouse							323	959	1282	1,1	1410		1622					1622			
	Perpignan							323	1128	1451	1,1	1596		1836					1836			
	Avignon							323	970	1293	1,1	1422		1636					1636			
	Marseille							323	1056	1379	1,1	1517		1744					1744			
London	Bordeaux							124	846	970	1,1	1067		1227					1227			
	Bayonne							124	1031	1155	1,1	1271		1461					1461			
	Toulouse							124	959	1083	1,1	1191		1370					1370			
	Perpignan							124	1128	1252	1,1	1377		1584					1584			
	Avignon							124	970	1094	1,1	1203		1384					1384			
	Marseille							124	1056	1180	1,1	1298		1493					1493			
Antwerp	Frenkendorf									587	1,1	646		743					743			
	Vorarlberg									767	1,1	844		970					970			
Rdam Mv	Frenkendorf									718	1,1	790		908					908			
	Vorarlberg									857	1,1	943		1084					1084			
	Slaskie									1302	1,1	1432		1647					1647			
Bordeaux	Slaskie									2143	1,1	2357		2711					2711			
Bayonne	Slaskie									2328	1,1	2561		2945					2945			
Toulouse	Slaskie									2079	1,1	2287		2630					2630			
Perpignan	Slaskie									2073	1,1	2280		2622					2622			
Avignon	Slaskie									1851	1,1	2036		2342					2342			
Marseille	Slaskie									1829	1,1	2012		2314					2314			

The load units on a train belong to numerous customers, some having small, others having large load units, and with no cost equalisations between these. Therefor the cost competitiveness should be analysed separately for different load unit types instead of investigating the cost competitiveness for the average load unit size. We have carried out such analyses for

- full trainloads and ideal wagons: 88 (x 20’) load units, 44 (x 40’) load units, 40 (x 45’) load units;
- less-than-full trainloads or non-ideal wagons: 37 (x 45’) load units, and 32 (x 45’load units).

In other words, the train costs are divided by respectively 88, 44, 40, 37 and 32 load units. The smaller number of trainloads can also be read as a lower loading degree (e.g. 40 of 44 ≈ 90% loading degree; or 32 of 40 ≈ 80%). The results are shown by Tables 7.9 b-f.

What are the results? For **20’containers** more or less all all-rail chains are cost competitive at the flow level of 30% and most of them even at 20%.
For (44 x) **40’ containers** the picture very much resembles that of the 1,7 TEU load unit, except that the flow size required for UK chains is slightly higher, and except that Daventry-Rotterdam moves into the critical zone (= almost cost competitive at the flow level of 100%).
With (40 x) **45’ load units** also Daventry-Poland moves in to the critical zone.[27]

Table 7.9 a The cost competitiveness of all-rail (IM) chains (1,7 TEU load units on the train)

51 x 1,7 TEU load units per train			
From / to	A	Eastbound IM chain is competitive	westbound IM chain is competitive
Daventry	Rdam RSC	feasible	feasible
	Slaskie	feasible	feasible
	Bordeaux	feasible	feasible
	Bayonne	feasible	feasible
	Toulouse	feasible	feasible
	Perpignan	feasible	feasible
	Avignon	feasible	feasible
	Marseille	feasible	feasible
London	Bordeaux	feasible	feasible
	Bayonne	feasible	feasible
	Toulouse	feasible	feasible
	Perpignan	feasible	feasible
	Avignon	feasible	feasible
	Marseille	feasible	feasible
Antwerp	Frenkendorf	feasible	feasible
	Vorarlberg	feasible	feasible
Rdam Mv	Frenkendorf	feasible	feasible
	Vorarlberg	feasible	feasible
Rdam RSC	Slaskie	feasible	feasible
Bordeaux	Slaskie	feasible	feasible
Bayonne	Slaskie	feasible	feasible
Toulouse	Slaskie	feasible	feasible
Perpignan	Slaskie	feasible	feasible
Avignon	Slaskie	feasible	feasible
Marseille	Slaskie	feasible	feasible

feasible	= feasible given flow share of 20%
feasible	= feasible given flow share of 30%
feasible	= feasible given flow share of 50%
feasible	= feasible given flow share of 100%
feasible	= almost feasible given flow share of 100%
	= not feasible

[27] Birmingham, another West Midland terminal, might still be cost-competitive as the PPH distances to the most important customers are shorter and therefore the PPH costs lower.

Tables 7.9 b-e (continuation) The cost competitiveness of all-rail (IM) chains (other types of load units on the train. Legend: see Table 7.9a)

90 x 20' load units per train

From / to	B	Eastbound IM chain is competitive	westbound IM chain is competitive
Daventry	Rdam RSC	feasible	feasible
	Slaskie	feasible	feasible
	Bordeaux	feasible	feasible
	Bayonne	feasible	feasible
	Toulouse	feasible	feasible
	Perpignan	feasible	feasible
	Avignon	feasible	feasible
	Marseille	feasible	feasible
London	Bordeaux	feasible	feasible
	Bayonne	feasible	feasible
	Toulouse	feasible	feasible
	Perpignan	feasible	feasible
	Avignon	feasible	feasible
	Marseille	feasible	feasible
Antwerp	Frenkendorf	feasible	feasible
	Vorarlberg	feasible	feasible
Rdam Mv	Frenkendorf	feasible	feasible
	Vorarlberg	feasible	feasible
Rdam RSC	Slaskie	feasible	feasible
Bordeaux	Slaskie	feasible	feasible
Bayonne	Slaskie	feasible	feasible
Toulouse	Slaskie	feasible	feasible
Perpignan	Slaskie	feasible	feasible
Avignon	Slaskie	feasible	feasible
Marseille	Slaskie	feasible	feasible

44 x 40' load units per train

From / to	C	Eastbound IM chain is competitive	westbound IM chain is competitive
Daventry	Rdam RSC		
	Slaskie	feasible	feasible
	Bordeaux	feasible	feasible
	Bayonne	feasible	feasible
	Toulouse	feasible	feasible
	Perpignan	feasible	feasible
	Avignon	feasible	feasible
	Marseille	feasible	feasible
London	Bordeaux	feasible	feasible
	Bayonne	feasible	feasible
	Toulouse	feasible	feasible
	Perpignan	feasible	feasible
	Avignon	feasible	feasible
	Marseille	feasible	feasible
Antwerp	Basel	feasible	feasible
	Vorarlberg	feasible	feasible
Rdam Mv	Basel	feasible	feasible
	Vorarlberg	feasible	feasible
Rdam RSC	Slaskie	feasible	feasible
Bordeaux	Slaskie	feasible	feasible
Bayonne	Slaskie	feasible	feasible
Toulouse	Slaskie	feasible	feasible
Perpignan	Slaskie	feasible	feasible
Avignon	Slaskie	feasible	feasible
Marseille	Slaskie	feasible	feasible

40 x 45' load units per train

From / to	D	Eastbound IM chain is competitive	westbound IM chain is competitive
Daventry	Rdam RSC		
	Slaskie		
	Bordeaux	feasible	feasible
	Bayonne	feasible	feasible
	Toulouse	feasible	feasible
	Perpignan	feasible	feasible
	Avignon	feasible	feasible
	Marseille	feasible	feasible
London	Bordeaux	feasible	feasible
	Bayonne	feasible	feasible
	Toulouse	feasible	feasible
	Perpignan	feasible	feasible
	Avignon	feasible	feasible
	Marseille	feasible	feasible
Antwerp	Frenkendorf	feasible	feasible
	Vorarlberg	feasible	feasible
Rdam Mv	Frenkendorf	feasible	feasible
	Vorarlberg	feasible	feasible
Rdam RSC	Slaskie	feasible	feasible
Bordeaux	Slaskie	feasible	feasible
Bayonne	Slaskie	feasible	feasible
Toulouse	Slaskie	feasible	feasible
Perpignan	Slaskie	feasible	feasible
Avignon	Slaskie	feasible	feasible
Marseille	Slaskie	feasible	feasible

37 x 45' load units per trein

From / to	E	Eastbound IM chain is competitive	westbound IM chain is competitive
Daventry	Rdam RSC		
	Slaskie		
	Bordeaux	feasible	feasible
	Bayonne	feasible	feasible
	Toulouse	feasible	feasible
	Perpignan	feasible	feasible
	Avignon	feasible	feasible
	Marseille	feasible	feasible
London	Bordeaux	feasible	feasible
	Bayonne	feasible	feasible
	Toulouse	feasible	feasible
	Perpignan	feasible	feasible
	Avignon	feasible	feasible
	Marseille	feasible	feasible
Antwerp	Frenkendorf		
	Vorarlberg	feasible	feasible
Rdam Mv	Frenkendorf	feasible	feasible
	Vorarlberg	feasible	feasible
Rdam RSC	Slaskie	feasible	feasible
Bordeaux	Slaskie	feasible	feasible
Bayonne	Slaskie	feasible	feasible
Toulouse	Slaskie	feasible	feasible
Perpignan	Slaskie	feasible	feasible
Avignon	Slaskie	feasible	feasible
Marseille	Slaskie	feasible	feasible

Tables 7.9 f (continuation) The cost competitiveness of all-rail (IM) chains (other types of load units on the train. Legend: see Table 7.9a)

32 x 45' load units per train			
		Eastbound	westbound
From / to	F	IM chain is competitive	IM chain is competitive
Daventry	Rdam RSC		
	Slaskie		
	Bordeaux	feasible	feasible
	Bayonne	feasible	feasible
	Toulouse	feasible	feasible
	Perpignan	feasible	feasible
	Avignon	feasible	feasible
	Marseille	feasible	feasible
London	Bordeaux	feasible	feasible
	Bayonne	feasible	feasible
	Toulouse		
	Perpignan	feasible	
	Avignon	feasible	feasible
	Marseille	feasible	feasible
Antwerp	Frenkendorf		
	Vorarlberg		
Rdam Mv	Frenkendorf	feasible	feasible
	Vorarlberg	feasible	feasible
	Slaskie	feasible	feasible
Bordeaux	Slaskie	feasible	feasible
Bayonne	Slaskie	feasible	feasible
Toulouse	Slaskie	feasible	feasible
Perpignan	Slaskie	feasible	feasible
Avignon	Slaskie	feasible	feasible
Marseille	Slaskie	feasible	feasible

With 37 load units on the train, the trainload expected by the pilot operators for Poland and Switzerland, also Antwerp-Frenkendorf moves into the critical zone, meaning that two of the pilot spokes are critical ones in terms of cost competitiveness. This, however, does not mean that the train service would not be commercially viable, as most Frenkendorf and most Slaskie chains are competitive already for small flow sizes. Cost equalisation by pricing, operational optimisation and adjusting the relative high cost level for the Swiss connection are solutions in this regard.

With (32 x) **45' load units** on board of the train, as expected by the UK rail operator, the all-rail chains UK-Poland and UK-Rotterdam are completely non-competitive in cost terms, while for France - Rotterdam and France - Poland chains all-train transport is feasible already on the 20% flow level. The other major market, UK - France, requires flow levels of 50% or more. Rotterdam - Frenkendorf or Rotterdam - Vorarlberg, can be run on the flow levels of 20% or 30%, dependent on the direction. UK - Poland and UK - Rotterdam go by short sea.

The flow levels to be expected and therefore all of these conclusions must be confirmed by the modal shift analysis. Until then and on the other side, the lower flow levels which apply for many all-rail chains, seem to be easy to achieve.

7.5 Zooming into the cost-competitiveness of rail from and to the UK and significant changes expected on the short term

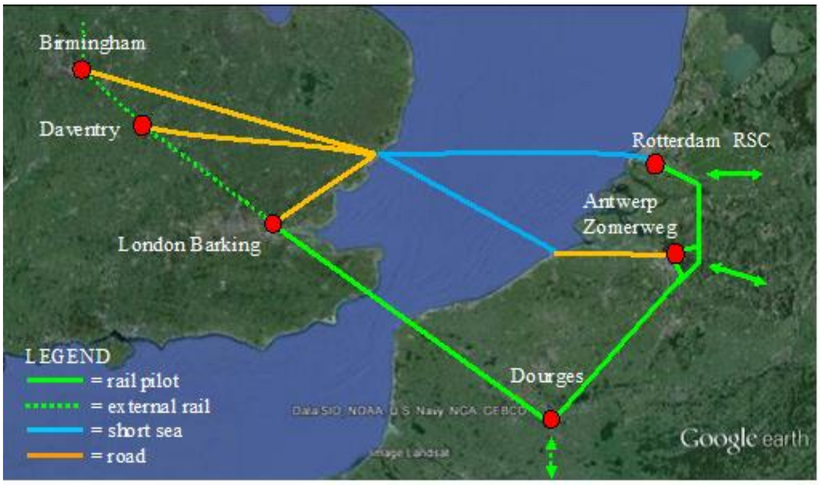
Rotterdam in comparison to Antwerp

As already indicated above, all-rail chains of 45’ load units between Daventry or London on the one side and Rotterdam on the other side are not cost competitive because of the very low prices of short sea transport between different UK seaports and Rotterdam. A detailed cost comparison can be found in Appendix 6, in which there are minor deviations to the costs shown in Table 7.2 (e.g. administration and path costs).

A very important impact of this conclusion is that also all-rail chains between Daventry or London on the one side and hinterland terminals accessed by rail from Rotterdam on the other side are non-competitive. For the pilot this means that all-rail services Daventry - Rotterdam - Poland or in general Daventry - Rotterdam - X cannot compete with the reference chains truck-short sea-train.

For Antwerp this conclusion does not or hardly does apply. The reason – and major difference to Rotterdam is – that there are much less short sea connections between Antwerp and the UK. Most UK-Belgium short sea connections go to Zeebrugge instead of Antwerp. The distance between Zeebrugge and Antwerp needs to be covered, typically by truck or train (Figure 7.8), inserting an additional cost in the short sea chains. In addition, the train distance and costs between the UK and Antwerp are less than to Rotterdam. These operational differences make the difference in cost-competitiveness (Appendix 6) between Rotterdam and Antwerp and further (via Rotterdam or via Antwerp). Getting attached to Antwerp rail services from the UK (Daventry or London) by train is reasonable, getting attached to Rotterdam trains not.

Figure 7.8 The difference of short sea competition for Rotterdam and Antwerp, due to a land leg in Antwerp short sea chains



Costs of short sea connections will increase in 2015 significantly

The European Commission has launched new regulations dealing with sulphur emissions from sea vessels in the channel, North sea and Baltic sea. The emission levels allowed by 2015 are reduced significantly from 1% to 0,1%.
The regulations also effect short sea shipping which can react to the challenge by either buying cleaner fuels or by installing filtering equipment on board the vessels. Experts (Anderson and Drewry, 2014) state that the costs for low sulphur fuel will be about 50% more expensive than traditional fuel.

Since fuel costs have a high share in the operational costs of short sea shipping such cost increases will change the competitiveness of rail transport from and to the UK and to and between coastal regions. Looking over the cost comparison of Appendix 6 one can conclude that all-rail chains between the UK and Rotterdam are likely to become cost competitive in 2015. This new perspective and opportunity will already play a role for the pilot.

Quality-competitiveness of all-rail chains

The rail competitiveness next to costs also depends on the quality of transport services. When designing pilot train services, quality issues were:

- visiting more than one intermediate node on a spoke (e.g. UK) can extend the door-to-door time to non-competitive sizes;
- exchanging load units between trains at an intermediate node functions well of the dwell time of load units at the node is short. The node visit of involved trains needs to be synchronised, surely if the service frequency is less than a work daily service. The best synchronisation is the simultaneous visit of trains at the exchange node. Rail synchronisation can also be of relevance of reference chains includes slow modes with high frequencies, as is the case for short sea transport between the UK and Rotterdam.
- calculating with too short dwell times of trains at hubs in favour of acceptable the aim of achieving certain roundtrip times can lead to missing other train services at the hub with serious consequences for the door-to-door times of load units and the manageability of correction measures..

Part C Twin hub services on the long term

8 Identification of promising Twin hub networks on the long term: development and application of a bundling tool

8.1 The identification challenge

(E. Kreutzberger)

One can imagine the Twin hub network or comparable networks to evolve to a large scale feature, increasingly substituting wagon load systems and road transport, responding to the growth of the intermodal rail sector, and also responding to the "eternal" presence of less-than-trainload flows.[28]

On this larger scale it merely is impossible to identify promising Twin hub networks by hand. The identification needs to be supported by a tool. Its aim is to design Twin hub rail services, other rail services, and road services, providing transport for all flows of an origin destination matrix (or a selection of the matrix) while minimising system transport costs. The cost minimisation focuses, contrary to many models, not on **minimising distances**, but on **maximising** the size of **trainloads**.

Such tool, the Twin hub **Bundling tool**, has been developed in the Twin hub project (part of Action 2). This chapter describes the Bundling tool and its results, reflects on the value the tool adds to existing models, and gives a brief outline of planned future elaborations of the tool.

8.2 The types of transport services in reality and in the Bundling tool

(E. Kreutzberger and S. Meijer)

As mentioned in part A of this report, intermodal rail flows which have the size to fill a direct train on the required frequency level should by transported by direct trains. However, many flows, also ones from and to large transport nodes as large seaports, are too small to fill a train on the frequency level aimed at. They need to be transported "complexly" or by road. As for other modes also in the rail sector hub-and-spoke networks are a promising type of complex bundling networks.

Twin hub is the title for a set of hub-and-spoke networks each consisting of a ***batch*** of train (service)s, which mutually exchanging load units at the hub. The hub exchange can take place simultaneously (= directly between trains) or sequentially (= between trains via the terminal storage). Additionally, train services belonging to a hub-and-

[28] The latter two developments might seem contradictive, but are not, because the growth of the intermodal sector is accompanied by:

- the shift of flows from the market of complex rail bundling networks to the market of direct trains. The market of e.g. hub-and-spoke networks shrinks;
- the shift of flows from the road market to the market of complex rail bundling networks. The market of e.g. hub-and-spoke networks grows.

spoke network, can be line services, meaning that the trains visit several rail-road terminals, typically at the beginning or the end of their journey (as the French trains in Figure 6.2). Furthermore, there may be trains running only on one side of the spoke, for instance any Antwerp train having flows for Rotterdam in combination with one train between the hinterland and Rotterdam passing and exchanging at Antwerp. Last, although hardly discussed in this report up to now, there may be exchange between two hub-and-spoke networks.

Correspondingly, the tool designs a variety of transport services, in order to move all flows of the matrix; transport services such as:
1. direct train services;
2. a set of hub-and-spoke networks, each having one or more ‘indirect trains’;
3. (optionally) train services to the hub;
4. (optionally) train services from the hub;
5. direct truck services;
6. (optionally) truck services to the rail hub;
7. (optionally) truck services from the rail hub.

During the run of the project it became increasingly clear that in regions with a lot of waterways, barge is likely to play a role, also in networks dominated by hub-and-spoke train services. Barge has – given its low costs – the potential to substitute one or more rail spokes in a hub-and-spoke network, in particular if the distance of a spoke is short.
This network design option is not yet part of the Bundling tool.

8.3 Hub exchange

(E. Kreutzberger and R. Konings)

The rail-rail exchange at hubs in Twin hub networks could consist of exchanging wagon groups between trains. But if all service types mentioned in Section 8.2 are active, the hub needs to be a terminal. The mentioned service types imply load unit transhipment at the hub between trains of a hub-and-spoke network[29], between the trains of different hub-and-spoke networks[30], and (optionally) between to-hub trains and from-hub trains[31]. And there may be rail-road transhipment between a rail spoke and a road spoke[32].

The Twin hub concept perceives the hub locations to be or lie close to the gravity points of involved flows, therefore in the region Rotterdam and Antwerp. Later, enlarging the concept to northern France, a third hub region, the Calais-Lille region. Within each region a concrete terminal needs to be chosen, like the Mainhub Antwerp or its substitute Zomerweg terminal, like RSC in Rotterdam or an imaginary Rotterdam location for a future hub terminal, and in France the terminal Dourges.

The tool is planned to have the flows “choose” which of the hubs should be chosen. Then some hub-and-spoke networks would run via Rotterdam, others via Antwerp

[29] = within service type 2 in Section 8.2.
[30] = between different 2s.
[31] = between different 3s.
[32] = hence between service types 3 and 7 or 6 and 4.

and again others via Antwerp. Both hubs are in operation, whether Twin hub networks make use of it or not. In the current state of the tool the tool can incorporate only one hub location at a time. The first runs of the tool have been carried out with Antwerp.

The Twin hub trains visit existing (or future) terminals which are public meaning that also other networks or train services use the terminal.

8.4 Twin hub bundling problem

(E. Kreutzberger and S. Meijer)

8.4.1 Corner stones of the Twin hub bundling problem

When designing a transport network it is important to clarify what exactly the design challenge (problem) is, including answers to the following questions. What is to be optimised? What is the planning horizon? Who carries the risk of investments? Dependent on the challenge the nature of some operations needs to be explicated and distinction of fixed and variable costs may be required, while other operations Can be treated as back box, their costs well being represented by simple cost functions like integral kilometric costs per load.

Crainic and Laporte (1997) have surveyed the freight transportation planning domain, and discern three planning levels based on the time horizons at which the planning events take place. Strategic planning involves operations with long planning horizons, and consists of determining general development policies and operating strategies of the transport system. Tactical planning involves medium-term planning activities that consist of the efficient allocation of existing resources in order to improve the performance of the whole system. Operational planning involves short-term planning activities that are highly time-dependent, such as the (re)planning and (re)scheduling of individual vehicles, facilities, and activities.

Each of these planning categories deals with distinct types of challenges. Hub location models as in the work of O'Kelly (e.g. Bryan and O'Kelly, 1998) or Mayer (2000) are important examples of strategic hub-and-spoke network planning. These models investigate which (set of) hubs to open and to use. Should hub infrastructure be built? Should the risk be taken to open and run a hub facility? The network design focuses on minimising fixed hub costs per load or other transport unit. Therefor fixed and variable hub costs are distinguished. The interest in the cost effects of the bundling choice on the size of trainloads and train costs is limited. Train costs are modelled by simplified cost functions, often based on kilometric train costs per load unit or on route volume dependent concave cost curves.

The focus of the transportation planning problem in the Twin Hub project is on the bundling of flows through an existing transport network to form a transport schedule, in other words the design of the service network. This identifies the problem as a tactical planning problem. Tactical planning problems within intermodal transport planning are concerned with service network design (Crainic and Laporte, 1997). The Twin hub network design challenge (= "Twin hub bundling problem" = THBP = THB problem) is to minimise network costs by increasing trainload sizes. The major benefits of large trainloads are low fixed costs per load unit. Therefore the fixed costs of trains need to be explicated.

The hubs are public and of a long term planning level. The commercial risk of running a hub typically, although not necessarily[33], takes place outside of the Twin hub network. The integral hub costs are incorporated variably to the cost calculation of Twin hub operations, corresponding with the number of transhipments at the hub.

Summarising, the THBP, a tactical challenge, aims at scale effects and minimisation of fixed costs per load unit on the level of trains. Hub costs consist of a constant cost per load unit transhipped at the hub. Many hub facility models, being of a strategic nature, aim at scale effects and minimisation of fixed costs on the level of hub infrastructure, accepting simplified calculation of train costs per load unit.

Crainic and Laporte (1997) and Crainic (2000) have identified the following research issues within tactical planning of freight transport:

- **Service selection**: Transport route and frequency specification;
- **Traffic distribution**: Connection routing and terminal operation specifications;
- **Transport node policies**: Consolidation type specification;[34]
- **Empty balancing**: Redistribution policy of empty containers.[35]

While all four issues are relevant to service network design problems, **empty balancing** is dealt with separately in the Twin Hub optimisation problem.

The **service selection** problem focusses on determining the frequencies of the train and truck services based on the desired service frequencies between each origin-destination pair. The routes (= transport relations) between the regions/terminals are fixed by the aim to provide transport for the entire origin and destination matrix.

The **traffic distribution** and **transport node policies** are closely related tasks. Establishing a hub-and-spoke bundling means that there will be less (train) connecting routes through the network than would be the case in the – reference – direct train network. But this can only work if the involved trains visit the same hub to mutually exchange load units. The allocation of containers on trains and trucks and the exchanges at the hub - and the transport (bundling) policies for the hub and spoke bundling process, this classifies the optimisation challenge for the Twin Hub project.

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33 The Mainhub Antwerp is an example of a hub terminal being public, but having the trains of its owner being the only customers. Interferryboats then has the commercial risk of operating the terminal and its trains, hence dealing with a strategic and a tactical network design issue.

34 Crainic and Kim (1997) distinguish customised transportation systems next to consolidation transportation systems. Consolidation systems involve some form of bundling where one transport can contain loads originating from one or more sources to one or more destinations. Customized systems, on the other hand, provide a dedicated service to each customer. As bundling of load units at one of the two central hubs is a key policy requirement, a consolidation transport system will be used in the Twin Hub project.

35 An extension to this model was proposed by Macharis and Bontekoning [16] (updated by Caris *et al.* [2]) by making a distinction between four different decision makers: drayage operators, terminal operators, network operators, and intermodal operators. Within each combination of decision maker and time horizon, a number of planning problems are identified and relevant papers are mentioned.

8.4.2 Related problems

(S. Meijer, C. Witteveen and E. Kreutzberger)

A review of problems related to the THBP in existing literature reflects the fact that consolidation planning problems in intermodal transportation can have many different optimisation and policy goals. Some show resemblance with the THBP. Similar problems do not only arise in rail-road intermodal transportation problems, but can also be found in, for example, (intermodal) air transportation problems and LTL-trucking.

While there exists a large volume of research on service network design problems, None of the models in the reviewed papers formulate a problem similar to the THBP. Existing models:

- do not really apply the concept of indirect trains (or other vehicles), but instead interconnect vehicle services running on relative short route segments at nodes. In Bundling tool terms they only have to-hub trains and from-hub trains;
- and/or do not address the operational feature of vehicle (train) batches. A batch is a hub-and-spoke network with a limited number of spokes and trains, and characterised by the intention to organise most rail-rail exchange between the trains belonging to the that batch. In its most consequent version the trains of the hub-and-spoke network visit the hub simultaneously;
- and/or do not truly display the effects of vehicle loads. Instead of explicating fixed costs and calculating train costs per load unit, kilometric train costs per load unit, optionally varied by ex-ante scale factors, serve as input.

8.5 Modelling

8.5.1 Bundling tool

(S. Meijer, C. Witteveen)

The THB problem requires a new modelling approach, which incorporates its specific requirements. The literature review shows that even though similar problems have been studied in literature, the THB problem differs from these problems in terms of scheduling requirements (e.g. static vs. time-dependent service network formulation), modelling requirements (e.g. batch-structure), and optimisation target (minimization of true costs through flow aggregation on transports).

The modelling of the THB problem is an extension to the modelling of an intermodal transport system by Newman and Yano [17]. It incorporates the notion of a recurring schedule in which the transport methods are modelled explicitly, and a distinction is made between fixed costs - those costs associated with operating a train service - and variable costs associated with transporting an additional container on a train.

The modelling of the THB problem is not straightforward, and design choices must be made in order for the model to accurately reflect the real-world costs and constraints while limiting the complexity of the model for it to be efficiently solvable.

The following choices have been made in creating the model:

1. A schedule is made for the duration of one round-trip only to ensure periodicity of the schedule and ensure a pre-set minimum service frequency. This schedule is then repeated to fill the required planning horizon.

2. The schedule must ensure enough capacity to transport all predicted container flows within the planning period.
3. Transport methods (trains and trucks) are modelled as concrete instances, i.e. the costs are directly attributed to the use of transport methods on a specific link.
4. Trains cannot only move between two terminals, but can also visit one hub and route to a destination. These are called indirect trains.
5. No fixed costs exist on intermediate nodes (i.e. hubs). Instead, variable costs are charged for each train that visits a (hub) terminal and each container exchanged.
6. Transports arrive in batches (groups), with a limit on the number of trains in a batch. These batches have an ordering, but are not scheduled at a specific time.
7. Optimisation criteria are directly related to operational costs. A container can be transported using any combination of trains and trucks en route to its destination.

These design choices lead to a model that is both compact due to the static service network formulation with batches of trains, and provides sufficient detail to compute the train/truck, container, and terminal costs realistically.

8.5.2 Geographical structure

(E. Kreutzberger and R. Konings)

The bundling tool was initially developed for identifying promising Twin hub networks to connect NUTS 2 areas. Each of the areas is represented by a rail-road terminal. Which terminal to use within a region has been determined in discussions, by hand calculations and by applying the Euro terminal analysis (Appendix 3). Having chosen the terminal, the average PPH distance per NUTS 2 area could be determined, allowing the bundling tool to calculate the PPH costs per load unit. At the same time the costs of the reference mode, unimodal road transport, was included with one distance per NUTS 2 area, the distance between the seaport and the gravity point of the NUTS 2 area.

A closer look to this approach led to the conclusion that NUTS 2 areas are slightly too large to appropriately identify promising Twin hub networks. Working with one PPH distance for a relative large area will lead to an underrepresentation some NUTS 2 areas, as their PPH costs are too high and an overrepresentation of other NUTS 2 areas, as their PPH costs are too low.

Therefore the tool in a second phase has been modified, now focusing on the smaller NUTS 3 areas. The distances for PPH and for unimodal road transport have been individualised to that level. The NUTS 3 areas still are accessed via the terminal of the NUTS 2 area to which they belong.

In both phases the origin/destination matrix can be split into several parts, letting the tool run separately for each matrix. The first matrix refers to all regions that can be reached by day A/C services from the seaports, the second to regions located further away from the seaports. The reasoning for such distinction is the organisation of roundtrips. Having train batches in which all train services have the same frequency, visit the hub in the same rhythm or even simultaneously is difficult to organise if the distances and therefor the roundtrip times are very different.

8.5.3 Solver

(S. Meijer, C. Witteveen)

To solve the THBP, a Mixed Integer Linear Programming (MILP) formulation of the problem is created, which is also based on the MILP-formulation by Newman and Yano [17]. This means that all transport options (direct and hub-and-spoke transports) are enumerated. Containers can be transported using these options, using capacity on (part of) the journey of the transports. Stack exchanges are also modelled using an inventory of containers at the hub, and exchanges between transports are also modelled. The transports, container amounts, and exchanges are all integer decision variables to be decided by the MILP-solver, which tries to find an assignment to these variables that minimizes the costs under a set of constraints specifying the problem. The settings of these decision variables determine the resulting service network.

The number of (integer) decision variables in the MILP-model grows quickly relative to the number of terminals and batches, as container flows need to be tracked through the transport system. This tracking requires a substantial amount of variables, as for each container on an indirect train that is exchanged, not only the container's source and destination must be specified, but also the source (for from-hub transports) or destination (for to-hub transports) of the indirect train responsible for transporting the container on that leg of its journey, and the batch in which this train visits the terminal. This formulation still leaves some ambiguity in the case when there are two indirect trains in a batch with the same source terminal or destination terminal.

Containers may then be transported on either of these trains to or from the hub, as this does not influence the costs of the solution. To resolve this ambiguity, an assignment of containers to trains is made upon reconstruction of the service network from the MILP decision variables. Some integer variables may be relaxed to speed up the MILP solver. While relaxing the variables specifying the trains must remain integer due to the fixed costs per train, the decision variables denoting the amount of containers on each (leg of the) journey of a train and the exchanges at the hub can be made continuous without affecting the accuracy of the cost calculation too much. An additional post-processing step is required to round any non-integer amount of containers to be transported, possibly leading to minor inefficiencies upon rounding. However, this adaptation greatly reduces the number of integer variables in the model, and is expected to cause a significant speedup in calculating good quality solutions.

8.6 Results

8.6.1 Results direct from the tool

(E. Kreutzberger, S. Meijer)

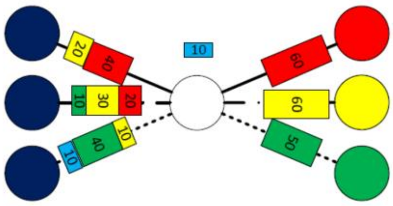
The output the tool consists of loading information of involved transport services and the related cost performance information. We can recall the quintessence of the loading information, for hub-and-spoke batches, namely the number of load units on a train per directional group, and the number of load units leaving or entering trains at the hub (Figure 8.1). The latter load units come from or go to other batches, single (direct) train services and/or truck services.

The result of a tool run is an overview of:

- batches, each consisting of more than one of three train types 2-4 in enlisted in Section 8.2 and optionally also of truck services,
- direct trains,

- truck services, as shown in Table 8.1.

Figure 8.1 Description of trainloads and their transformation at the hub
(S. Meijer, 2012)



The information to each batch can be opened, the tool then displaying (Table 8.2):

- the number of trains involved in a batch;
- the type of involved trains;
- the name of the begin terminal and the name of the inland region;
- the number of load units on a train to the hub;
- how many of them will be transhipped to another train or to the storage area of the hub terminal;
- or how many of them will stay on the train at the hub;
- the number of load units on the train from the hub;
- how many of them come from another train or from the storage area;
- the amount of “savings” (= lower costs than the truck sector).If there are savings the amounts are displayed in a green field, otherwise in a red field.

Table 8.1 Overview of promising transport networks or single transport services (example* of the output of the bundling tool)

Batches (10 **)
Batch 0
Batch 2
Batch 3
Batch 4
Batch 5
Batch 6
Batch 7
Batch 8
Batch 9
Direct trains (23 ***)
Direct trucks (93)

* Result varies slightly dependent on set of cost and time inputs and on tool running time.
** Number of batches.
*** Number of single services.

The savings give reason to argue the optimisation criterion. The tool minimises system costs allowing that single networks or services do not cover their costs. In Table 8.2 the batches and services which do cover their costs are marked by green

Table 8.2 Promising Twin hub networks and other transport services: output of the bundling tool

Twin-Hub Bundling Tool

File Help

Run Configuration | Solution - Jan2013_Ekki_1day_east_complexv71_default_b10

Solution statistics

Problem information	
Instance name	Jan2013 1day_east_complexv71_default_b10
Number of sources	5
Number of destinations	53
Maximum number of batches	10
Number of O/D flows	240
Number of containers	3774
Solution statistics	
Solution costs (per container)	2180441,28 (577,75 / container)
Actual number of batches	10
Mean number of containers per train, per batch (min/mean/max/stdev)	(33,93 / 47,68 / 56,79 / 6,57)
Max/min difference per batch (min/mean/max/stdev)	(8,84 / 21,73 / 37,18 / 8,17)
Offloaded containers per batch (min/mean/max/stdev)	(62 / 120,40 / 239 / 55,40)
Loaded containers per batch (min/mean/max/stdev)	(76 / 120,40 / 163 / 24,27)

Solution	2180441,28	Savings: 251103,72	
Batches (10)	947580,90		
Batch 0	126595,50	Savings: 87567,50	
Trains (3)	111499,50		
Indirect train (LONDON -> hub -> Total FR42)	36681,00	Savings: 28367,00	<(d16 + s40 + t4) = 60> ▼ 40 -- 16 --> ▲ 32 <(d16 + s32 + t12) = 60>
Indirect train (West Midlands -> hub -> Total FR10)	37380,02	Savings: 25337,98	<(d18 + s32 + t10) = 60> ▼ 32 -- 18 --> ▲ 32 <(d18 + s32 + t8) = 58>
Indirect train (Manchester -> hub -> Total DE92)	37438,48	Savings: 33862,52	<(d1 + s47 + t12) = 60> ▼ 47 -- 1 --> ▲ 30 <(d1 + s30 + t6) = 37>
Trucks (8)	15096,00		
Batch 1	128286,52	Savings: 76440,48	
Trains (3)	108313,52		
Indirect train (LONDON -> hub -> Total FR71)	45599,10	Savings: 35282,90	<(d19 + s41 + t0) = 60> ▼ 41 -- 19 --> ▲ 41 <(d19 + s41 + t0) = 60>
Indirect train (West Midlands -> hub -> Total DE94)	46611,42	Savings: 28572,58	<(d4 + s56 + t0) = 60> ▼ 56 -- 4 --> ▲ 56 <(d4 + s56 + t0) = 60>
Dest train (hub -> Total DE71)	16103,00	Savings: 12585,00	(--> ▲ 44 <(s44 + t0) = 44>
Trucks (11)	19973,00		
Batch 2	88344,58	Savings: 35334,42	
Trains (3)	75826,58		
Indirect train (Rdam -> hub -> Total FR23)	34422,40	Savings: 7621,60	<(d32 + s28 + t0) = 60> ▼ 28 -- 32 --> ▲ 28 <(d32 + s28 + t0) = 60>
Dest train (hub -> Total DEA4)	17512,09	Savings: 9199,91	(--> ▲ 53 <(s53 + t0) = 53>
Dest train (hub -> Total FR26)	23892,10	Savings: 18512,91	(--> ▲ 55 <(s55 + t0) = 55>
Trucks (4)	12518,00		
Batch 3	84032,45	Savings: 46299,55	
Trains (3)	75374,45		
Indirect train (Rdam -> hub -> Total DE13)	36604,60	Savings: 12847,40	<(d36 + s24 + t0) = 60> ▼ 24 -- 36 --> ▲ 24 <(d36 + s24 + t0) = 60>
Dest train (hub -> Total DE60)	20178,50	Savings: 20441,50	(--> ▲ 60 <(s60 + t0) = 60>
Dest train (hub -> Total DE11)	18591,35	Savings: 13010,65	(--> ▲ 46 <(s46 + t0) = 46>
Trucks (3)	8658,00		
....			
Batch 9	85763,73	Savings: 52236,27	
Trains (3)	73990,73		
Dest train (hub -> Total FR24)	21783,22	Savings: 14276,78	(--> ▲ 60 <(s60 + t0) = 60>
Dest train (hub -> Total DE27)	21332,67	Savings: 16034,34	(--> ▲ 43 <(s43 + t0) = 43>
Dest train (hub -> Total FR52)	30874,84	Savings: 21925,16	(--> ▲ 60 <(s60 + t0) = 60>
Trucks (4)	11773,00		
Direct trains (23)	609242,38		
Direct train (Rdam -> Total FR10)	23379,13	Savings: 2835,88	(49) ----> (49)
Direct train (Rdam -> Total FR10)	23734,89	Savings: 3015,11	(50) ----> (50)
Direct train (Rdam -> Total DE94)	33401,84	Additional: -4841,84	(60) ----> (60)
Direct train (Rdam -> Total DE92)	27184,22	Savings: 2515,78	(60) ----> (60)
Direct train (Rdam -> Total FR42)	26346,68	Savings: 7557,32	(52) ----> (52)
Direct train (Rdam -> Total DE71)	21759,83	Savings: 2850,17	(46) ----> (46)
Direct train (Rdam -> Total DE12)	23517,50	Savings: 3718,50	(44) ----> (44)
Direct train (Rdam -> Total DE60)	27725,78	Savings: 7554,22	(60) ----> (60)
Direct train (Rdam -> Total DE11)	25303,46	Savings: 5251,54	(45) ----> (45)
Direct train (Rdam -> Total FR41)	28894,24	Savings: 4045,76	(60) ----> (60)
Direct train (Rdam -> Total FR71)	34474,94	Savings: 15822,06	(53) ----> (53)
Direct train (Antwerp -> Total FR10)	25169,23	Savings: 731,78	(59) ----> (59)
Direct train (Antwerp -> Total FR10)	25513,86	Savings: 826,14	(60) ----> (60)
Direct train (Antwerp -> Total FR10)	25513,86	Savings: 826,14	(60) ----> (60)
Direct train (Antwerp -> Total FR10)	25513,86	Savings: 826,14	(60) ----> (60)
Direct train (Antwerp -> Total FR23)	30347,96	Savings: 1152,04	(60) ----> (60)
Direct train (Antwerp -> Total FR42)	27464,92	Savings: 5775,08	(60) ----> (60)
Direct train (Antwerp -> Total FR21)	23575,50	Additional: -10496,50	(29) ----> (29)
Direct train (Antwerp -> Total FR41)	27082,00	Additional: -22,00	(60) ----> (60)
Direct train (Antwerp -> Total FR41)	27082,00	Additional: -22,00	(60) ----> (60)
Direct train (Antwerp -> Total FR41)	27082,00	Additional: -22,00	(60) ----> (60)
Direct train (Antwerp -> Total FR71)	29018,00	Savings: 8426,00	(44) ----> (44)
Direct train (LONDON -> Total FR10)	20156,70	Savings: 1527,30	(39) ----> (39)
Direct trucks (92)	623618,00		

fields, the others in red ones. The tool alternatively allows to optimise under the condition that all batches are profitable in comparison with unimodal road transport or even that each single service is profitable.

The bundling tool also produces statistics on the solution as a whole (all transport services) as the number of containers per average batch and the deviations.

8.6.2 Results via the tool interface

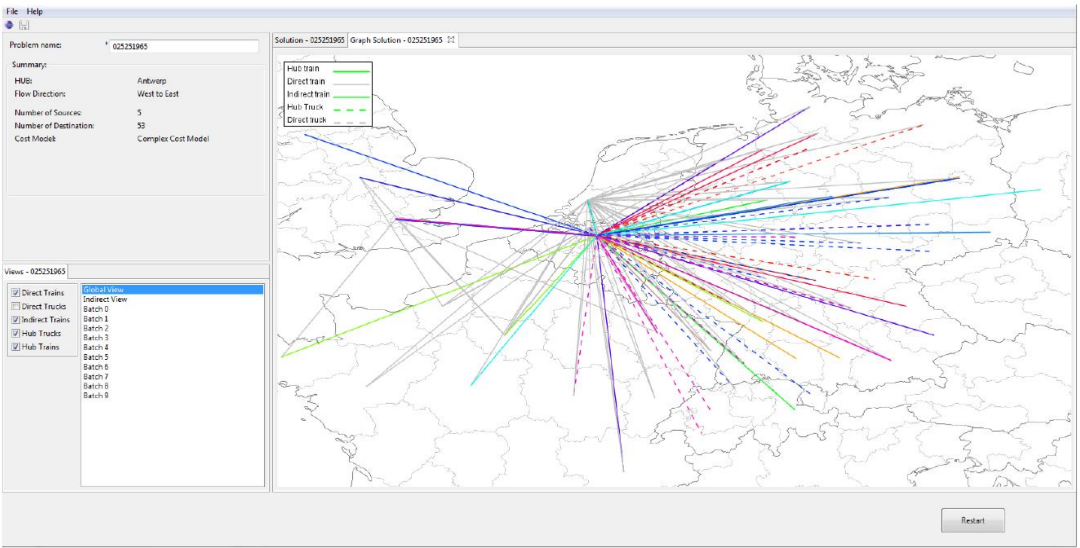
(E. Kreutzberger, S, Meijer and C. Witteveen, with support of M.Pors, J. Tetteroo, C. van der Valk, C.Witteveen)

The THBP instance and the resulting service network design both contain a large amount of information which is difficult to interpret from the data. Therefore, an interface has been developed for the convenient specification of a problem instance for the solver, and the processing of the MILP-solution to form a solution to the THB problem.

To aid in the evaluation of the solutions, an interactive geographical visualisation of the generated service networks is integrated in the tool. The visualisation can show and hide batches and different types of transports, can show detailed specifications of each batch, transport, and the containers on each transport, and can present statistics on the solution as a whole. This allows for the selection of promising batches, analysing the plausibility of the generated transport services, and evaluating the performance of the service network itself.

Figure 8.2 shows a visualisation of the entire transport network, hence of all transport services required to move flows of the envisaged O/D-matrix from Rotterdam, Antwerp and the UK directly or via the hubs content being comparable with the information in Table 8.1. Continuous lines represent train services, dotted line truck services. Lines of a certain colour belong to the same batch. Many flows go

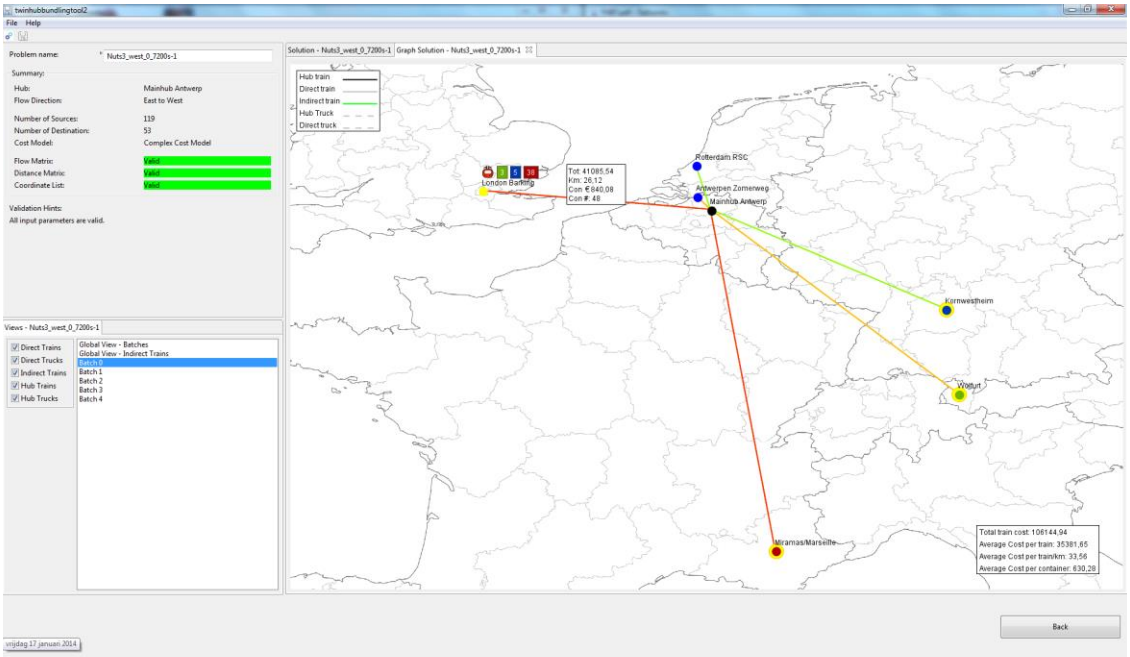
Figure 8.2 An output map displaying the total network opened



(Source: Pors, Tetteroo, and Van der Valk, 2012) by direct train. If on a connection there is direct rail and road transport, only the rail is visible. That can be the case for direct transport and for indirect (rail) or to- or from-hub (rail or road) services.

The interface can also visualise single hub-and-spoke batches. Figure 8.3 shows one consisting of three indirect trains starting in France, Austria, and Germany, meeting at the hub in Antwerp, and continuing their respective journeys to the UK, Belgium, and the Netherlands. In the visualisation, the UK spoke is highlighted showing the number of load units coming from Kornwestheim (5 LUs, blue), Wolfurt (3 LUs, green) and Marseilles (38 LUs, red).

Figure 8.3 The visualisation of a hub-and-spoke batch in the bundling network



8.7 Conclusions and future tool development

(E. Kreutzberger, S. Meijer)

A bundling tool has been developed to solve the Twin Hub Bundling problem and visualize the solution the solver generates. The tool has resulted in a set of rail hub-and-spoke networks and other transport services. None of the hub-and-spoke networks completely corresponds with the pilot one. This is not surprising as the choice of the train services in the pilot network was driven by many factors which are articulated differently in the tool or the input for the tool. An example is the difference between the flow matrix and the flow expectations of rail operators due to customers envisaged or contracted.

In addition, the tool still has a number of limitations which ought to be eliminated by future research. The most important one is modelling complete roundtrips instead of half roundtrips. This creates the possibility of matching flows in both directions. The consequence is that certain rail services may become non-competitive due to the small

size of retour trainloads. At the same time, other connections may become suitable for rail transport, as a rather small trainload is made competitive by a very large trainload in the opposite direction.
An interesting extension of the bundling tool is the incorporation of time scheduling. The creation of hub-and-spoke networks does depends on combining flows on the basis of trainload sizes, but also on the basis of the time characteristics of the exchange at e.g. the hub.

Other opportunities to improve the underlying model refer to the algorithms[36] and the applicability of the tool by practitioners[37] and are not elaborated in this report.

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[36] Efficiency improvements of the tool. To date, there only exist solvers that aim for solving the problem to optimality. By using heuristics or approximation algorithms that aim to find a satisfactory solution quickly, we aim to enable iterative workflows, where the consequences of changing certain parameters can be visualized more easily.

[37] Improve the user experience with the tool to decrease the learning curve for new users. Preliminary tests have shown that working with the tool requires either a strong affinity with computers and programming, or extensive training to understand how to process jobs. Improving this could lead to adoption of the tool by other operations research teams.

Part D Conclusions

(E. Kreutzberger and R. Konings)

9 Conclusions

Analyses confirm on two levels that the Twin hub concept is a relevant concept.

- On the level of flows it allows organising full trainloads and/or higher transport frequencies for more inland terminals than if each seaport bundles flows on its own. In total there were 19 NUTS II regions having enough flows in case of seaport bundling and not enough otherwise. In addition there were 4 NUTS II regions for which the large seaports would have sufficient flows on their own, but which – by Twin hub bundling – can improve the level of service.
- On the level of door-to-door costs the Twin hub pilot train services are cost-competitive. There is one exception, at least until the end of 2014: some road-shortsea-rail chains are likely to be cheaper than all-rail chains. Such is the case for London-Rotterdam and further and for Daventry-Rotterdam and further, given large load units like 45' containers. Such is not the case for Birmingham-Rotterdam and further and also not for UK-Antwerp and further. The competitiveness is very much influenced by the road legs in the cost chain, for instance in the UK or between Zeebrugge, the main Belgian shortsea port – and Antwerp where most rail connections begin and end. From 2015 shortsea costs will increase substantially due to European regulation in the field of sulphured gases. The cost increase will make most all-rail chains cost-competitive.
  The cost-competitiveness was subject of a sensitivity analysis, exploring which proportion of the potential flows is sufficient to achieve competitive Twin hub services. For large load units 50% of the potential flows is sufficient for most transport relations, 30% for many relations. The modal shift analysis (upcoming) is to validate the expectations. In practice the rail operators have to find customers providing the required flow sizes.

The pilot is to test the Twin hub concept in practice. The main experience in this field up to now refers to the planning of the pilot network. The pilot network decided on were based on the analyses (promising regions, promising services) of the project. The rail operators had a heavy voice in this process, given their commercial responsibility.

The Twin hub pilot network decided on in 2013 very well featured the initial intentions for the pilot, all train services visiting a central hub and mutually exchanging load units. One pilot train started running in October 2013. The others did not follow, undermining the feasibility of the first train. It was stopped in January 2014. At that time the project consortium changed. A new pilot network was defined. And this looked quite different from the initially intended pilot. The 2014 pilot network basically consisted of three pilot networks, each centred around a different hub, namely Dourges, Antwerp Zomerweg and Rotterdam RSC. A pilot train exchanges load units with non-pilot trains: the UK train with French trains at Dourges, and the Swiss train with Belgian trains in Antwerp, The Poland train with Dutch trains in Rotterdam. The Rotterdam hub is the only one with inter-pilot train exchange, the UK train and Poland train being interconnected there. If the Poland train has Antwerp-Poland load units, which at the moment of the editing of this report was not yet known, there may also be interaction between the Basel and the Poland trains. One could see this as the result of a process in which the first stage has been skipped. The pilot network 2014 rather resembles what the network was expected to

look like in the second stage, not consisting of only one hub-and-spoke network integrating the flows of different seaports (and the UK), but of several ones.
The project has invested into tool development. Important results are:

- the improvement and actualisation of the Rail cost model (RACOM; TUD);
- a new bundling tool (TUD) to transform a flow matrix into a set of transport services on the basis of integer linear programming. The transformation goes hand in hand with determining the modal split, on an all-or-nothing basis. The first generation of the tool has been improved, now starting from flows between smaller areas (NUTS 3 instead of NUTS 2 regions). The latter is still being tested. First results for the area UK (Manchester, West Midlands and London), Germany and France, and again starting from the road container flows 2010, are nine rail hub-and-spoke batches with roughly 30 trains involved of which 14 throughgoing ones at the hub, next to direct trains not visiting the hub and next to a lot of unimodal road transport;
- the improved and spatially extended Euroterminal model (VUB). It is made to identify regions for which rail is cost-competitive. A major improvement is the substitution of kilometric total train costs per load unit by fixed and variable train costs implying that the size of trainloads now makes a difference for the train costs per load unit. The model in this project was mainly applied to identify the best begin-and-end terminal in a NUTS 2 region, minimising (unweighted) pre- and post-haulage distances in the region.

Appendix 1 Project management

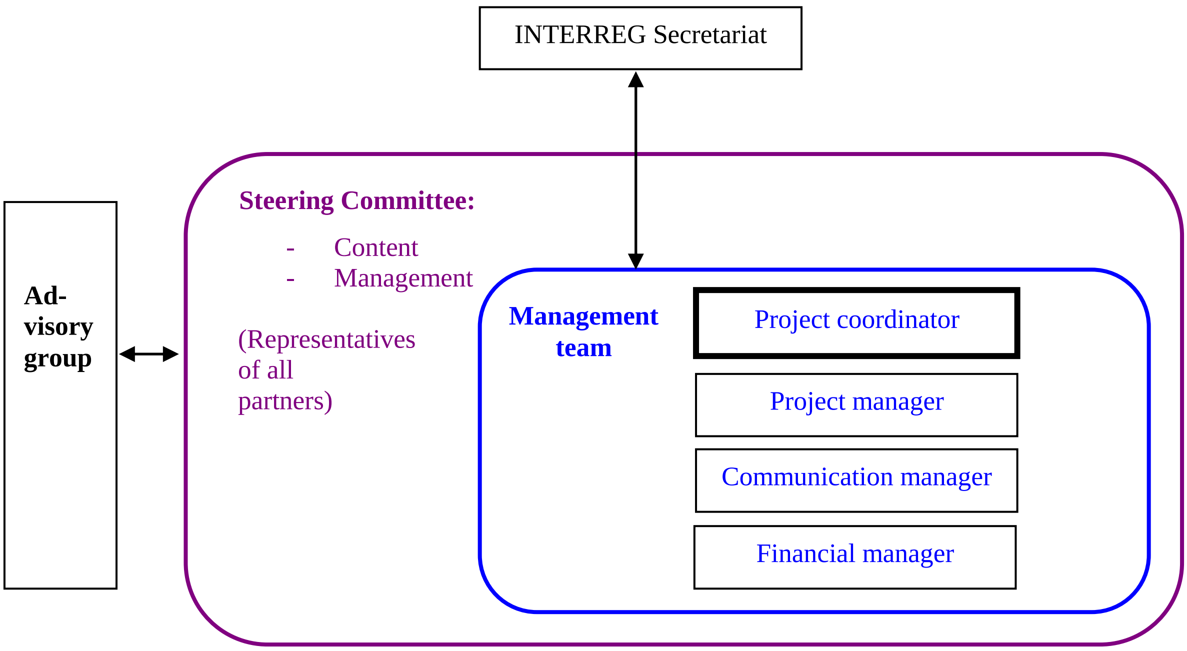
The Delft University of Technology is the project leader. The management team of the Twin hub project consists of the project coordinator, the project manager, the communication manager and the financial manager (Figure A1). These functions will be carried out by respectively the Research institute OTB (research), the Valorisation Centre and the Research Institute OTB (Communication). The management team is the communication channel between the project and the Secretariat of INTERREG NW Europe in Lille. It coordinates the contents, finances and processes of the project and the communication, and it writes the periodic progress reports to Lille.

The Steering Committee consists of a management and a content part. The management part is attended by the management representatives of each partner, the content part by content representatives of each partner. The content or management representative of a partner can be the same person.

Each half year the project meets. Part of the meeting time is reserved for the Steering Committee, part for the general discussion of project contents, results and other issues. The partners are free to send more persons to the meeting than their representative(s), dependent on the agenda.

Each work package has WP-meetings, which take place as frequent as useful. The WP leader organises them.

Figure A1 Management structure of the project Twin hub project



Appendix 2

Summary transport flow analysis of Zeeland seaport region *(W. Vos)*

Research has been done to estimate the potential flow of goods in the region of the ports of Zeeland suitable for a modal shift from road to train. In this research a total of 27 companies has been involved after contacting a total of 65 companies. In the table below the companies are enlisted which transport their cargo in intermodal load units and which - after a first analysis - may be interesting for the Twin Hub Network project.

Overview of companies in the Zeeland region which are transporting their cargo by intermodal loading units at the moment or have the potential to put it in intermodal loading units.		
Vlissingen - Oost	**Terneuzen region (Canal zone)**	**Outside port areas**
Verbrugge Terminals	Dow Benelux	Lamb Weston
Vopak	Bertschi	McCain
Kloosterboer	Yara	Monie
Arkema	Outokumpu	MSP
BOW terminal	Verbrugge Terneuzen	C.Meijer
Heerema Marine Contractors	Cargill	
	ICL-IP	
	Katoennatie	
	Heros Sluiskil	

In the field research the main focus was on first visiting the companies inside both port areas. With mostly all of above companies there has been an interview. Some of them will be visited for a deep interview in the coming period including the companies outside the port area.

The way of transport of the researched companies is mainly based on the items price and reliability. A number of companies say a lack of reliability is an important reason nowadays not to choose for transport by rail. Especially the image of railway transport in France is recognized as insufficient. Safety is a main item for the chemical companies. Transport by rail is considered as safe.
A global overview of the results about required transport conditions and motivation in the current situation u can find below:

Importance of the conditions by choosing mode of transport	
Criteria	**%**
Price	35%
Reliability	22%
Transit time	16%
Flexibility	12%
Sustainability	8%
Safety	8%
Track & Trace	0%

Motivation why companies in the Zeeland region don't choose for (container) railtransport at the moment	
Motivation	**%**
Impossibility at the customers	24%
Inflexibility	16%
Type of cargo / packaging	12%
No railconnection at terminal	12%
Price	12%
Customer decides	8%
Unreliability	8%
Unsuitable handling material	4%
Transit time	4%

A distinction has been made between the companies in the port of Vlissingen, in 'de Canal zone' and in the companies outside the port of Vlissingen. The flow of goods is separated in the inbound flow and the outbound flow.

The analysis aims at the flow of goods to and from the European hinterland nowadays transported by truck, but in potency suitable for shipping by train. The goods are packed in containers or are suitable for packing in containers.

The inbound flow of goods, suitable for a modal shift from road to train, has a potency of about 2.600 TEU with a majority of goods from Russia (Table A2.1).

Table A2.1 Inbound flow of goods in TEU

Company Type Line of business Location		**Total of 1 Vlissingen**		**Total of 1 Kanaalzone**		**Grand Total**	
Hinterland	**Country**						
Northern Europe		0		0		0	
	Finland		0		0		0
	Norway		0		0		0
Eastern Europe		3.667		0		3.667	
	Russia		3.667		0		3.667
Southern Europe		0		0		0	
	Italy		0		0		0
	Spain		0		0		0
	Portugal		0		0		0
Western Europe		0		0		0	
	Germany		0		0		0
	France		0		0		0
	UK		0		0		0
	Rest		0		0		0
Unkown		0		1.267		1.267	
Way of transport							
Road			2.000		633		2.633
Water			1.667		633		2.300
Rail			0		0		0

The outbound flow of goods (Table A2.2), suitable for a modal shift from road to train, has a potency of about 226.000 TEU with a majority of 190.000 TEU from companies from ‘de Kanaalzone’. In the region Weil am Rhein ‘de Kanaalzone’ transports about 2.250 TEU a year. In Vlissingen there is an opportunity of about 16.000 TEU with a highlight in Germany. From the companies outside Vlissingen the results show 19.000 TEU transported by road to the European hinterland. However the specific destination of this outbound flow is not known.

Table A2.2 Outbound flow of goods in TEU

Company Type Line of business Location		Total of 3 Vlissingen			Total of 2 Kanaalzone			Total of 4 Outside Vlissingen			Grand Total		
Hinterland	**Country**												
Europe		0			0	0	0	33.666			33.666		
Northern Europe		221			221			0			441		
	Sweden		221			221			0			441	
	Norway		0		0	0	0		0				
	Finland		0			0			0				
Eastern Europe		1.015			9.682			0			10.697		
	Poland		960			960			0			1.920	
	02			0	0	0	0			0			0
	Estonia		9			9			0			19	
	Lithuania		46			46			0			91	
	Eastern Europe		0			8.667			0			8.667	
Southern Europe		1.129			31.675			0			32.804		
	Italy		0			30.547			0			30.547	
	Spain		1.016			1.016			0			2.032	
	Portugal		113			113			0			225	
Western Europe		15.623			375.849			1.000			392.472		
	Germany		11.228			328.121			0			339.349	
	01			0		0	224			0			224
	55			0			280			0			280
	64			0			56			0			56
	77			0			926			0			926
	78			0			25			0			25
	79			0			175			0			175
	France		2.659			45.992			0			48.651	
	67			0			466			0			466
	68			0			629			0			629
	88			0			42			0			42
	90			0			0			0			0
	UK		1.736			1.736			1.000			4.472	
	Rest		0			0			0			0	
Central Europe		220			220			0			440	0	
	Switzerland		220			220			0			440	
	Czech Republic		0			0			0			0	
	Austria		0			0			0			0	
Unknown		0			27.467			5.000			32.467		
Way of transport													
Road				16.040			191.107			19.116			226.262
Water				2.167			210.647			20.550			233.363
Rail				0			43.360			0			43.360

From Vlissingen to Rotterdam rail transport is possible over the Zeeuwse lijn. Transport to Antwerpen by rail is only possible with a detour through Rotterdam or Dordrecht.
From ‘de Kanaalzone’ to Rotterdam (“Kijfhoek”) a service line by rail is offered on a daily base. To Antwerpen service lines are available for barge and rail.

Infrastructural connection from the Zeeland seaports with the possible twin hubs in Antwerpen and Rotterdam will be further investigated and clarified in WP 3.

Appendix 3 The Euro terminal model

(E. Pekin and C. Macharis)

Introduction

This chapter will describe the Euro Terminal Model, which is the most elementary but spatially most detailed approach within the project Twin hub network. It is accepted that intermodal rail transport offers a competitive advantage to unimodal road transport for longer distances. Furthermore intermodal transport is an important tool to decongest the port area which has to deal with an ever increasing flow of containers to be handled and transported to the hinterland. The Euro Terminal analysis assigns flows in an all-or-nothing mode. If the Twin hub pilot trains accessing regions have the lowest door-to-door costs all flows to and from that region have rail transport, otherwise unimodal road transport.

The Euro Terminal Model is based on the LAMBIT (Location Analysis Model for Belgian Intermodal Terminals) methodology which has been developed to analyse the market areas of intermodal terminals and potential ones. Within the project Twin hub network, the Euro Terminal Model extends the geographical scope of the model from Belgium to the European level. First the methodology and second the results of the model will be explained.

Methodology

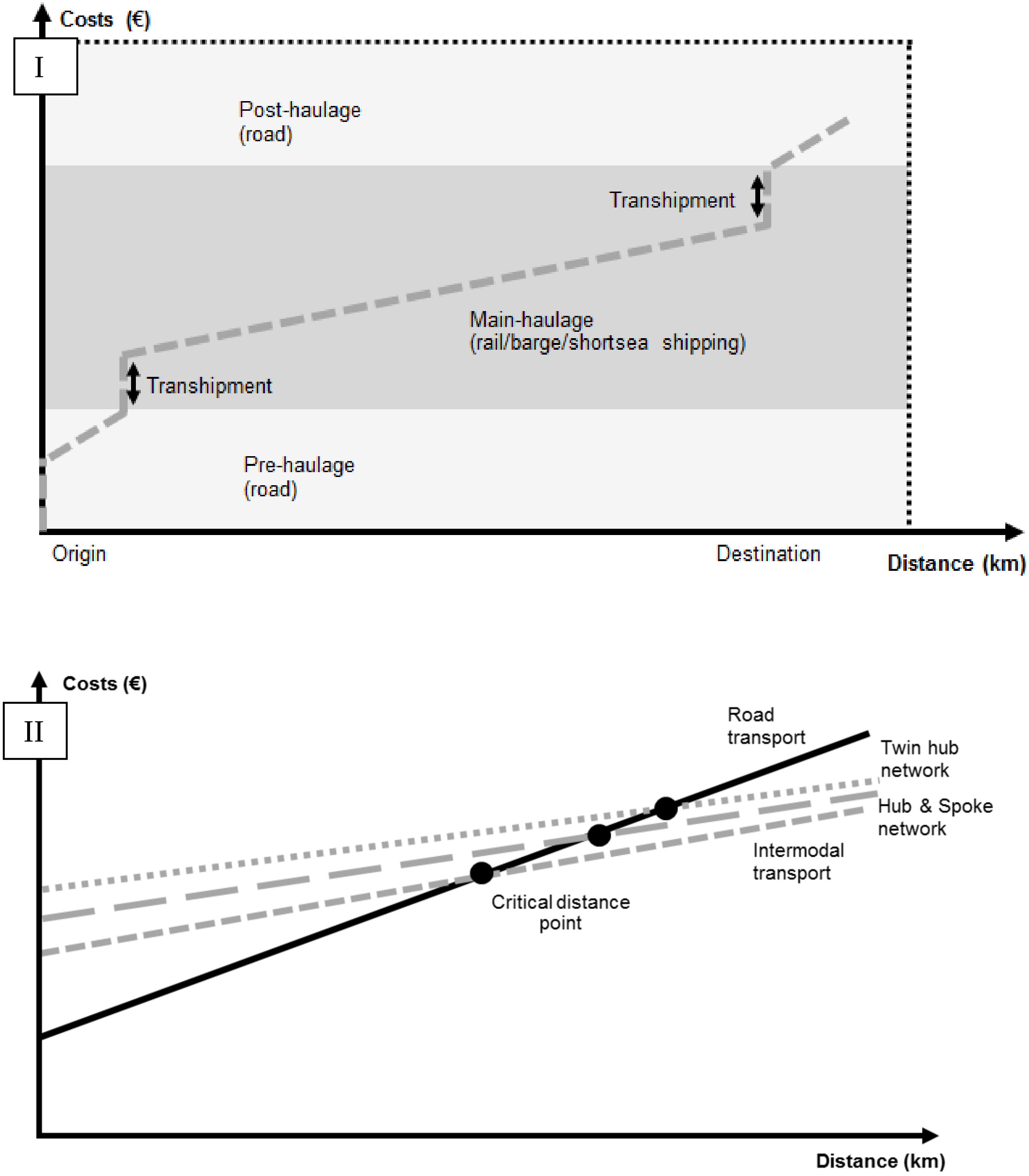
The LAMBIT methodology

The LAMBIT (Location Analysis Model for Belgian Intermodal Terminals) methodology (Macharis 2000 and Macharis and Pekin 2009) is extended and applied to the location analysis of intermodal rail terminals for the Twin hub promising routes.

Within the LAMBIT methodology three major components can be identified. The first component in the model is its inputs, with all sorts of data to be included in the analysis. The second component is the core model, a GIS (Geographic Information Systems)-based intermodal transport model, which performs analysis of policy measures. The GIS provides output, which constitutes the third component of the model such as maps with the market area of the terminals.

Utilising the intermodal cost function, the methodology performs a price (cost) minimisation approach. Figure 3.1 presents an intermodal cost function. For a door-to-door intermodal transport chain, the function allows to calculate total intermodal transport costs between an origin and a destination. Pre – and post – haulage requires interchanges from road transport to another transport mode in an intermodal terminal. In the upper part (I), the incurred costs are inserted chronologically, starting from loading for pre haulage, transhipment, main haulage, another transhipment, and, finally, end haulage. Note the comparatively steep inclination indicating a high cost per kilometre for the post-haulage by road. From the figure, it is possible to derive the importance of transhipments in an intermodal transport chain. An example of such transhipment is the hub operations in the Twin hub network.

Figure A3.1 Intermodal cost function



Source: own setup, 2013

In the lower part (II), all extra costs of transhipment and pre- and end haulage have been added from the start. Inserting a cost curve for unimodal road transport that is steeper due to the higher variable cost then allows for finding the critical distance point where unimodal road and intermodal freight transport is equally costly. Above that distance, intermodal transport is competitive from a cost perspective. The figure presents also hub and spoke and Twin hub network configurations. Higher fixed costs are incurred at the hub (due to complex bundling operations) placing these lines above intermodal transport line. Another observation is thanks to lower variable costs per kilometer their slope is lower.

Within the Twin hub concept, intermodal rail transport incurs larger handling costs compared to unimodal road transport. This is due to the extensive bundling operations that are used for the transhipment of containers on rail wagons. The main haulage is carried by rail. The advantage of intermodal transport lies in the smaller variable costs during main haulage, which are the result of the scale economies that are obtained by the large capacities that can be transported. As the variable costs of rail transport is cheaper compared to unimodal road transport, longer distance covered by the intermodal leg will make intermodal transport more efficient than unimodal road transport. However, at the end of the chain, an extra handling cost is incurred for the handling at the terminal in the hinterland.

The break-even distance reacts to the changes in the cost components of road and intermodal transport. The lines will move downward if the fixed costs decrease. For example, a decrease in the harbour dues would shift the dotted line downwards and reduce the break-even distance. The slope of the lines reacts to the changes in the variable costs. For example, an increase in fuel price would affect the variable cost of both unimodal road and intermodal transport. It will make the gray line steeper, shifting the break-even point to the left. Intermodal transport becomes more competitive, but this is tempered to some degree as the cost of pre- and post-haulage also rises.

Kim and Van Wee (2011) provide a recent overview on the break-even distances of the intermodal freight system. Two approaches can be employed to estimate the break-even distances. A first one is based on survey and interview approach. Some researchers use cost modelling in case studies to calculate the break-even distances. Here, studies use an equation to estimate and compare break-even distances for the current situation and certain scenarios. Literature includes numerous studies such as the Dutch Ministry of Transport which calculated break-even distances of 100-250 kilometres for inland navigation and 200-400 kilometres for railways (Van Duin, 2001). At a European scale, intermodal services over 600 kilometres are usually proven to be viable, while services over distances of 100 kilometres can rarely compete with unimodal road transport (Vrenken *et al.*, 2005). Literature also includes other cost factors such as empty container depot functioning of an intermodal terminal, congestion, and the distance of pre/post haulage because of their impact on the break-even distances. In the results section break-even analyses will be performed for the Twin hub network routes.

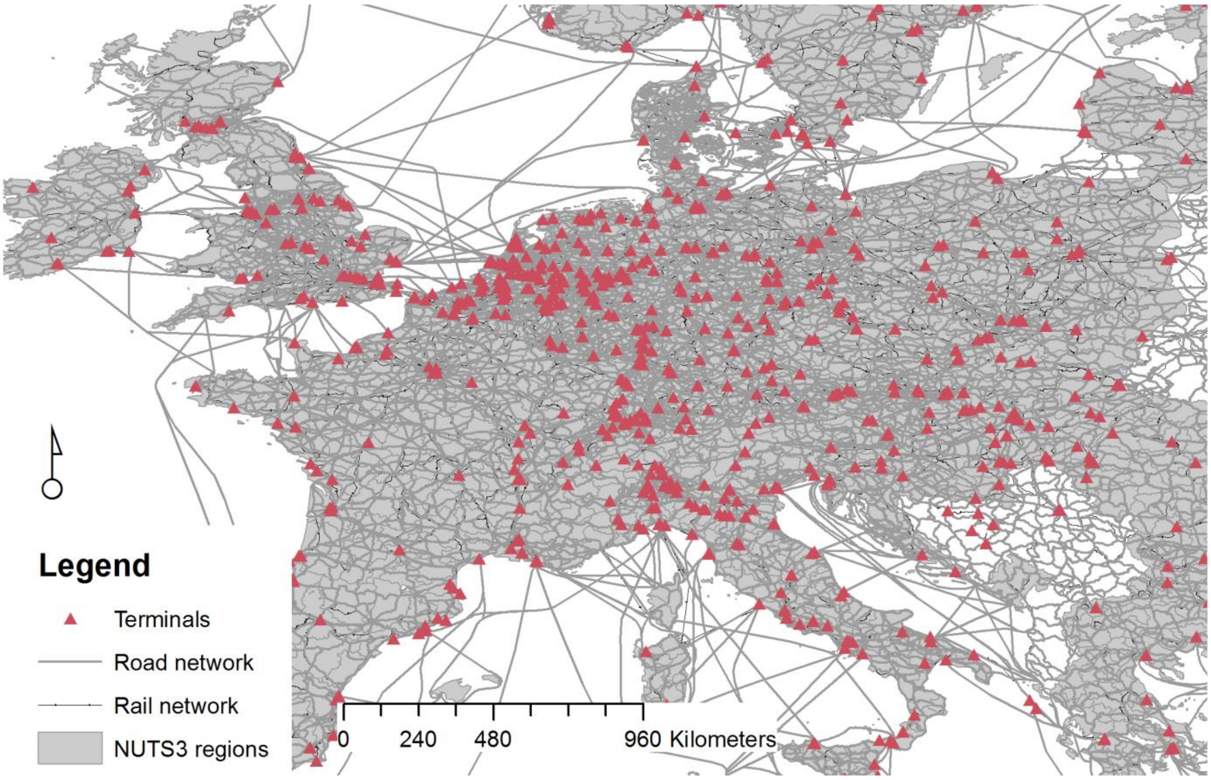
Model extension

The model is based on three main inputs: transportation networks, transport price functions, and demand for transport of containers from the regions to and from the sea ports.

Transportation networks

Geographical scope of LAMBIT was extended by the European intermodal network layers. The model has been built through connecting the geographic locations of the intermodal rail terminals (transhipment points) and the NUTS3 regions (end destinations) to the road and rail network layers by their corresponding nodes. During the set up process, possible Twin hub locations such as the Main Hub in Antwerp and RSC in Rotterdam are also included. Figure 3.2 depicts the layers of the network.

Figure A3.2 Network layers and nodes



Source: own setup, 2013

The Twin hub GIS network was built by merging the following digital databases:

- NUTS 3 region layers are obtained from Geographic Information System of the European Commission (GISCO).
- Road network and terminal location layers are obtained from the ETISplus database.
- Rail network layers are extracted from the ESRI (Environmental Systems Research Institute) dataset for Europe.

Transportation prices

In the second step of the model extension, an intermodal cost structure is developed to be used in break-even analysis, which is the concept behind the LAMBIT methodology. Considering the total transport prices and the distance travelled, unimodal road transport is cheaper over short distances, but once the break-even distance is achieved, intermodal rail transport offers a competitive alternative.

In the model, the following formula is used to calculate total intermodal rail costs:

$$TC = ((T \div (FF \times C)) \times D + W + H + O$$

where T is the traction (Euro per train kilometre) of the rail operators. In order to calculate the rate per TEU kilometre, fulfilment (FF) of the trains and their nominal capacity (C) are also considered. Here an assumption of 75% FF for trains of 85 TEU with nominal length capacity of 600 meters is made. It has to be noted that the Twin Hub network aims to increase FF of the trains, leading to lower rate per TEU. Once the rate per TEU kilometre is calculated, this variable cost is multiplied by (D) rail distance (kilometres). Then two fixed costs wagon costs (W)[38] and handlings (H) are added. Both of these cost components are expressed as Euro per TEU and incurred in the Twin hub and inland rail terminals. Finally the overhead (O) of 15% is coupled to arrive at the total intermodal rail cost.

For road transport (both for unimodal and pre - and post – haulage), fixed price and variable price functions are based on the existing market prices. Road prices differ for the Twin hub cases.[39] The calculated total transport prices for each transport mode are then associated with the network layers. The variable prices are uploaded to the network layers, and the fixed prices are attached to the nodes, which also indicate the origin and destination for each route and to the intermodal terminals in case of an intermodal trajectory.

Project partners (intermodal rail operators) are consulted to obtain data for the model. In order to have reliable transport prices average market prices were calculated. The assumption is that costs are included in these prices. Intermodal rail costs formula is an enhancement of the LAMBIT methodology where rail transport prices were calculated based on market prices.

Container flows

Another input for the model is the transport demand in terms of container flows to and from the port regions of Antwerp and Rotterdam. In the framework of the first phase of the Twin hub project, data from the European ETIS project that is processed by Pantheia (NEA) and analysed by Delft University of Technology (OTB) is used. Within the scope of Euro Terminal Model, only containers from/to the port regions of Antwerp and Rotterdam and from/to each NUTS3 region have been extracted and attached to the NUTS3 database. For a detailed overview on the flow analysis please consult Chapter 5 of the report.

Model operation

The model explores the relative attractiveness of two transportation modes (unimodal road and rail transport) through a price (cost) minimisation model. Following a break-even approach the total sum of transport prices is minimised in the model. Using a shortest path algorithm in ArcInfo, various scenarios are conducted in order to find the shortest path and the attached transport prices from the Twin hub (Port of Antwerp or Rotterdam) to each NUTS3 region via intermodal terminals and via unimodal road. For unimodal road market rate for truck transport is multiplied by the distance from the Twin hub location to each NUTS3 centres. For the intermodal rail rate per TEU kilometre is multiplied by rail distance from the Twin hub to each intermodal terminal. Fixed costs of wagons and handlings and overhead is added (see formula in previous sub-section). Intermodal rail price finally is calculated by the post-haulge that is taking place from intermodal terminals to the NUTS3 centres. The model uses extended post-haulage (forward move from an intermodal terminal).

For each destination (NUTS3 region), the total transport prices for unimodal road and rail/road transport from the Twin hub port locations are compared, and the cheapest

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[38] Wagon costs are expressed per TEU and are calculated assuming 8 wagons and 16 platforms per train.

[39] Road transport is cheaper in Poland compared to Switzerland routes.

option is selected. Each alternative option (intermodal terminal) is assigned a colour. The market area of each inland terminal in the Twin hub case regions is then highlighted in the map. These visualisations make it possible to see how large the market area of each intermodal terminal is. As a further step, the container flows data are used to show the amount of containers that are currently transported by road from the Twin hub port regions to the NUTS3 regions in the hinterland. This analysis gives an indication of the existing potential volume that can still be shifted within the market area of intermodal terminals in the hinterland.

Results

Two hinterland cases of the Twin hub pilot network are decided: Slaskie (Poland) and Basel (Switzerland) routes. For each case, an audit of the intermodal rail transport market will be made. Then results of the Euro Terminal Model analysis will be discussed.

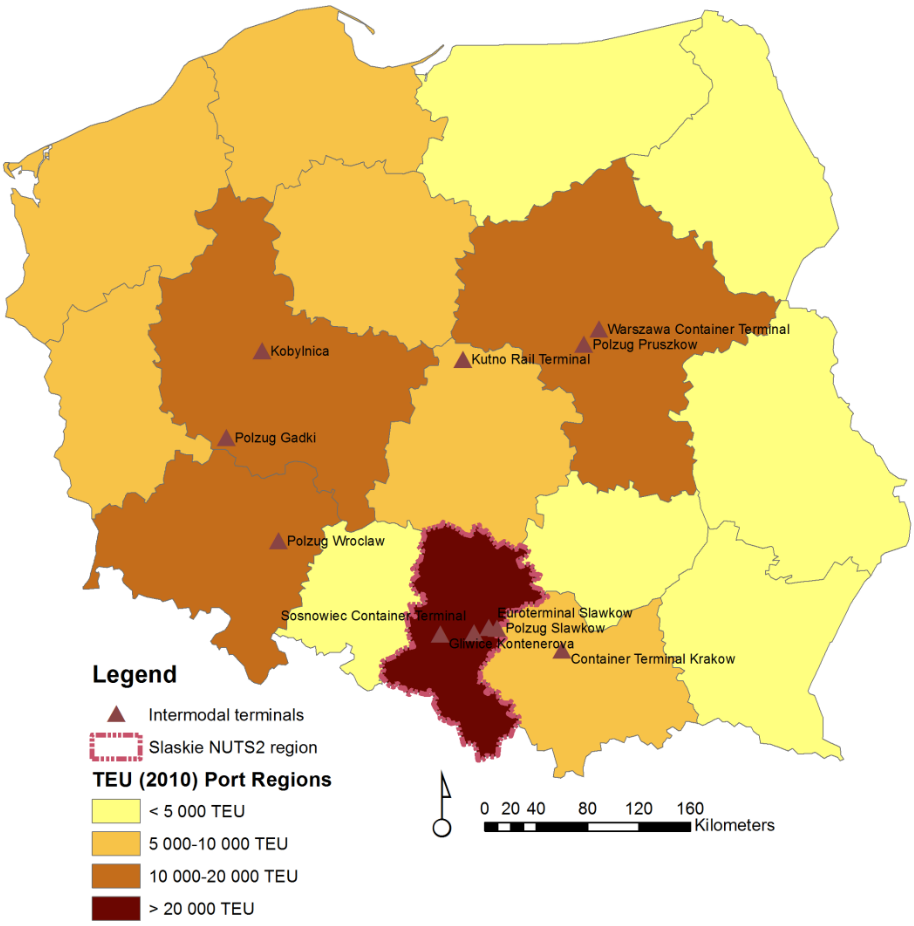
Slaskie case

Poland is mainly connected to Europe by a road network. Polish companies control the largest truck fleet in the EU. Taking 1996 as a reference, market share of intermodal rail transport increased from 0,7% to 1,1% in 2000 and to 1,7% in 2005. These figures indicate that intermodal rail transport still accounts for only a marginal part of the railway operations. Container transportation is the fastest growing transport segment in Poland. In 2005, 800.000 TEU were transported to/from in Poland. Polish seaports of Gdynia, Gdansk and Szczecin play an important role in this traffic. 56% of the container traffic is connected to the hinterland transport and is realised mainly by trucks. 44% of the container traffic is cross-border, originated from the European seaports of Hamburg, Bremerhaven and Rotterdam. Here, road and rail transportation have about 50% share.

Market leader in cross-border rail transportation of containers is Polzug Intermodal GmbH, a joint venture equally owned by PKP Cargo, Stinnes AG and HHLA Hamburg Port and Logistics AG. Main business of Polzug Intermodal is to offer hinterland transport services from North Sea ports to/from Poland. Polzug Intermodal connects Poland (via eight Polish terminals) with Hamburg, Bremerhaven and Rotterdam. In 2011 the production system of Polzug has been changed to a “hub concept” (UIRR, 2011). A new terminal in Poznan serves as the hub, where shuttle trains with multi-system locomotives are connected. This system aims to reduce the transit times to offer fast and reliable rail transport. Transit time for Hamburg-Poznan is now 12 hours without border stopping. Additionally, Polzug Intermodal is replacing old terminals by modern ones. In 2008 the terminal in Wroclaw was opened. This is followed by Dabrowa Gornicza in 2010 and the hub in Poznan in 2011. In 2013 Brwinow is foreseen to be opened near Warsaw.
Other railway operators are found in the market serving the Twin Hub network routes with their own products. For the Polish market from the port of Antwerp, Hupac and Kombiverkehr run seven destinations, sometimes directly, sometimes through Duisburg. From the port of Rotterdam Polzug, and Kombiverkehr are competitors.

The market overview above has to be coupled with the freight flow analysis to see if Polish regions have enough potential for initiating intermodal rail transport from the Twin hub seaport regions. Figure 3.3 show that the Slaskie province has the highest flows. In absolute terms the province accounts for more than 22.000 TEU. When flows from the UK are also integrated the potential increases to reach more than 46.000 TEU. Slaskie province is an industrial region with activities in mining, metallurgy, engineering, chemical, textile and the automotive sector. The province, which is one of the richest in Poland, also has good railway access with the longest so-called broad gauge railway line (the LHS line) in Poland. This line is designed for freight transport only and it connects Poland to Ukraine (LHS, 2013). The second region is Warsaw province, where flows are not reaching the threshold of Twin hub network. The province can have potential only when the flows from the UK are considered. Since there are already frequent rail services from the ports of Antwerp and Rotterdam, this region is not suitable for the Twin hub network.

Figure A3.3 Overview of container flows to Poland

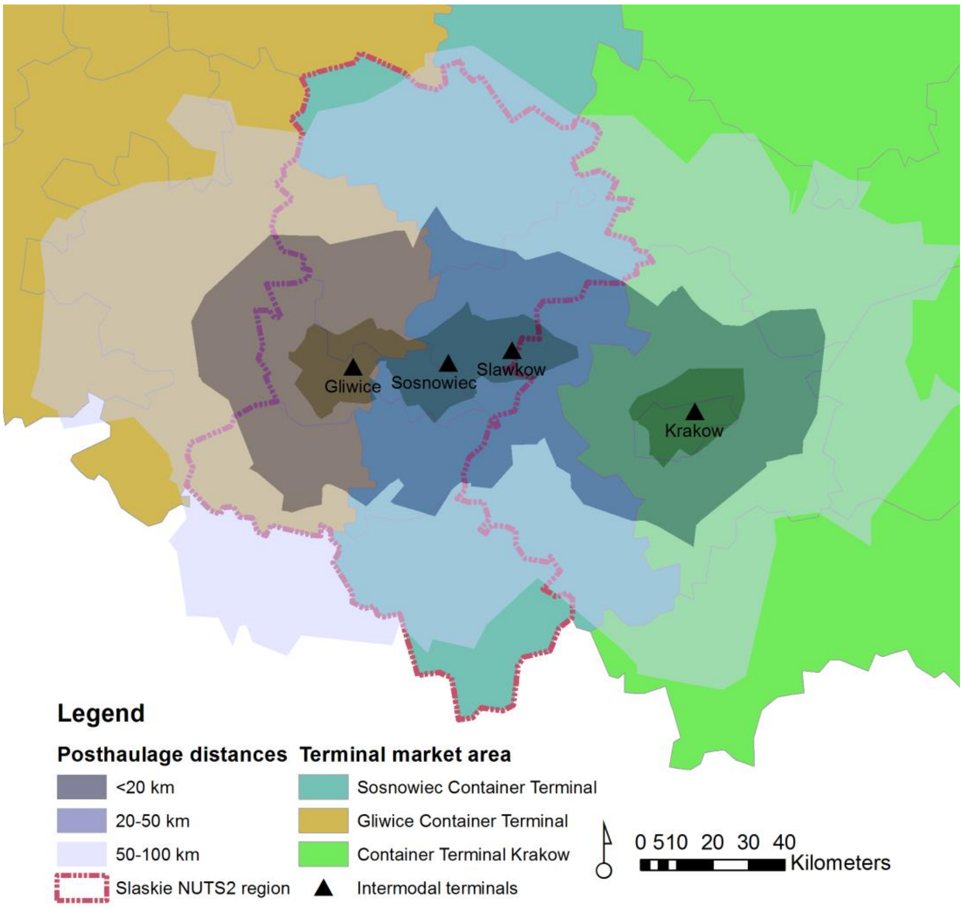


The next step is to investigate possible connections from Twin hub (Mainhub in Antwerp and RSC in Rotterdam) to the hinterland terminals in Slaskie province. Here attention is paid to the services that are already operating in the market as well. Results of the Euro Terminal Model highlight that rail services from RSC are cheaper compared to Mainhub[40]. Considering the Polish hinterland region from the western ports of Antwerp and Rotterdam, the terminal in Sosnowiec is the best option for

[40] The Euro Terminal Model calculates door-to-door costs for intermodal and unimodal road transport. Intermodal rail distance from RSC is shorter compared to Mainhub leading to a cheaper intermodal rail transport.

minimising the post-haulage. The market area analysis for Slaskie province is presented in Figure 3.4. The break-even distance for Slaskie case is 464 kilometres if a shorter post-haulage (20 kilometres) is foreseen[41]. When a longer post-haulage is needed the break-even distance reacts accordingly and increases up to 636 kilometres in the case of 100 kilometres of post-haulage.

Figure A3.4 Market area analysis for Slaskie region



The market area of the terminals can be represented as the number of NUTS3 regions that they attract flows. In Slaskie province there are 8 NUTS3 regions. In all of these regions intermodal rail transport is cheaper compared to unimodal road transport. The terminal in Sosnowiec can take 5 NUTS3 regions. The terminal in Gliwice has a share of 3 regions. The third terminal that is located in the province, Slawkow, cannot take any market area. Finally, the terminal in Krakow is also taking area but outside the Slaskie province. Depending on the distance of post-haulage from the terminal, intermodal transport prices increase. This is visualised by lighter shades in the market area in the figure. Darker shades indicate that intermodal rail is more competitive compared to unimodal road transport. There is no overlap between the shades and the NUTS3 borders.

[41] Break-even distances are expressed as road distances in kilometres.

Basel case

As an alpine transit country, Switzerland accommodates container flows connecting Northern and Southern Europe in a shortest way. Transalpine freight traffic through the Swiss Alps grew by about 60% between 1994 and 2010 (Mertel *et al.*, 2012). Considering the external effects of road transport, Swiss citizens voted to stop unbalanced growth in road freight transport thus construction of transit roads in the Alpine area were no longer accepted. In parallel, policy makers formulated multiple measures to achieve modal shift such as the modernisation of the railway infrastructure (especially the NEAT tunnels), the railway market reform and user (polluter) pays principle. Overall the goal is to improve the competitiveness of the rail freight transport. Positive results are already achieved since 2000. Rail transport started to offer better quality services with higher capacity. Share of rail freight increased to 66% and combined transport share in rail freight increased to 67% (Liechti, 2007). At the same time number of trucks in transit is reduced by 14%.

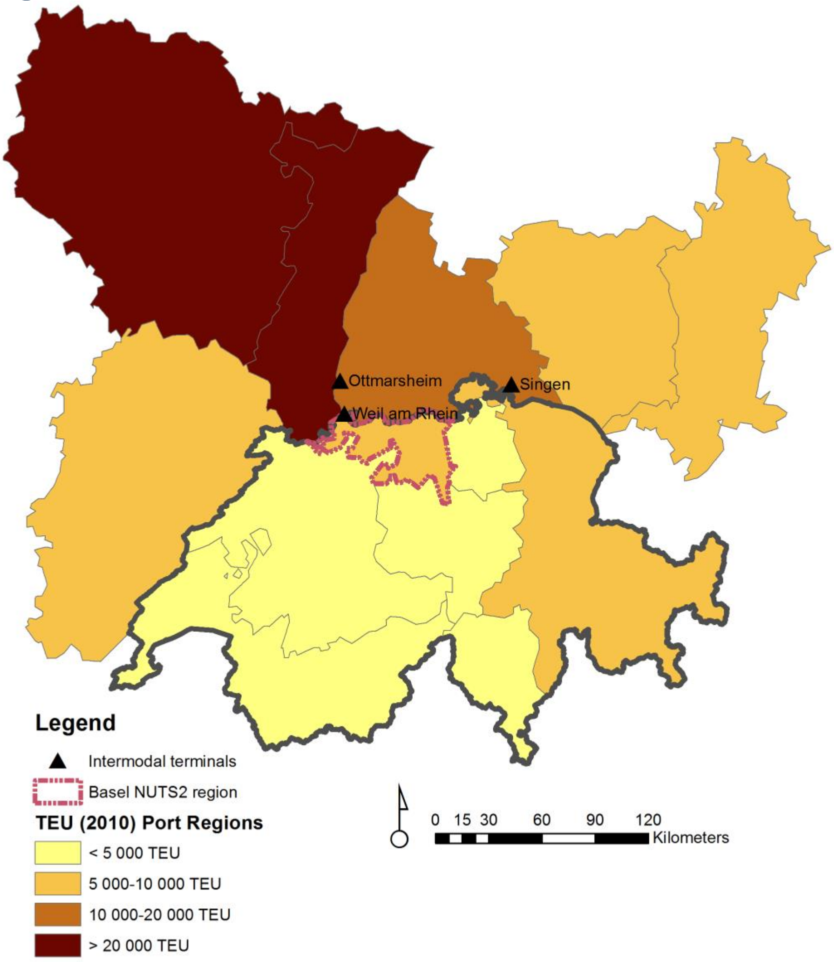
Examining the Swiss market with intermodal services from the Twin hub port regions, competition is seen especially from the port of Antwerp with IFB, Hupac and Kombiverkehr running trains to Basel. Only Hupac runs to Aarau. These railway operators also have services to the Weil am Rhein terminal which is located on the Swiss-German border, where MSC Medlog also is competing. From the port of Rotterdam Hupac and Kombiverkehr have services to Weil am Rhein.

The first step in performing the Euro Terminal Model analysis is to examine freight flows. The case is situated in the Basel region, specifically in Weil am Rhein in which the Swiss, French and German borders meet. The overview of container flows to Switzerland is provided in Figure 3.5. Here higher flow from the Twin hub port regions is seen in the French Lorraine and Alsace provinces that are located in the northern part of Basel. German province Freiburg also has higher flows compared to Basel itself. Nevertheless economically the neighbouring regions in Germany and France are not separated from the Basel thus real potential can be calculated with the Euro Terminal Model on the market area of intermodal terminals.

In Figure 3.6 the market area for intermodal terminals is examined with the Euro Terminal Model. The figure includes an extension from Basel to Voralberg region in accordance with the pilot train of IMS. The model results show that rail services from the Mainhub are cheaper compared to RSC due to shorter rail distances of the port of Antwerp to Basel. In the hinterland region, the terminal in Weil am Rhein can capture a major area in Switzerland including Basel. The break-even distance for the route is 384 kilometres if a shorter post-haulage (20 kilometres) is foreseen. When a longer post-haulage is needed the break-even distance reacts accordingly and increases up to 527 kilometres in the case of 100 kilometres of post-haulage. Compared to Slaskie case, the break-even is lower. This is explained by the higher road transport prices in Switzerland.

Whole Basel (3 NUTS regions) are in the market area of Weil am Rhein. The terminal also attracts two NUTS3 regions from Germany and one region from France over the Swiss border. Terminal in Ottmarsheim takes area in French NUTS3 regions and terminal in Singen takes Swiss and German NUTS3 regions. Terminal in Wolfurt on the other hand is competitive for Austrian and German regions. It also can take Swiss regions along the border. Figure 3.6 also provides gradual post-haulage distances, with the darker areas near the terminals have cheapest intermodal prices due to shorter post-haulage distances.

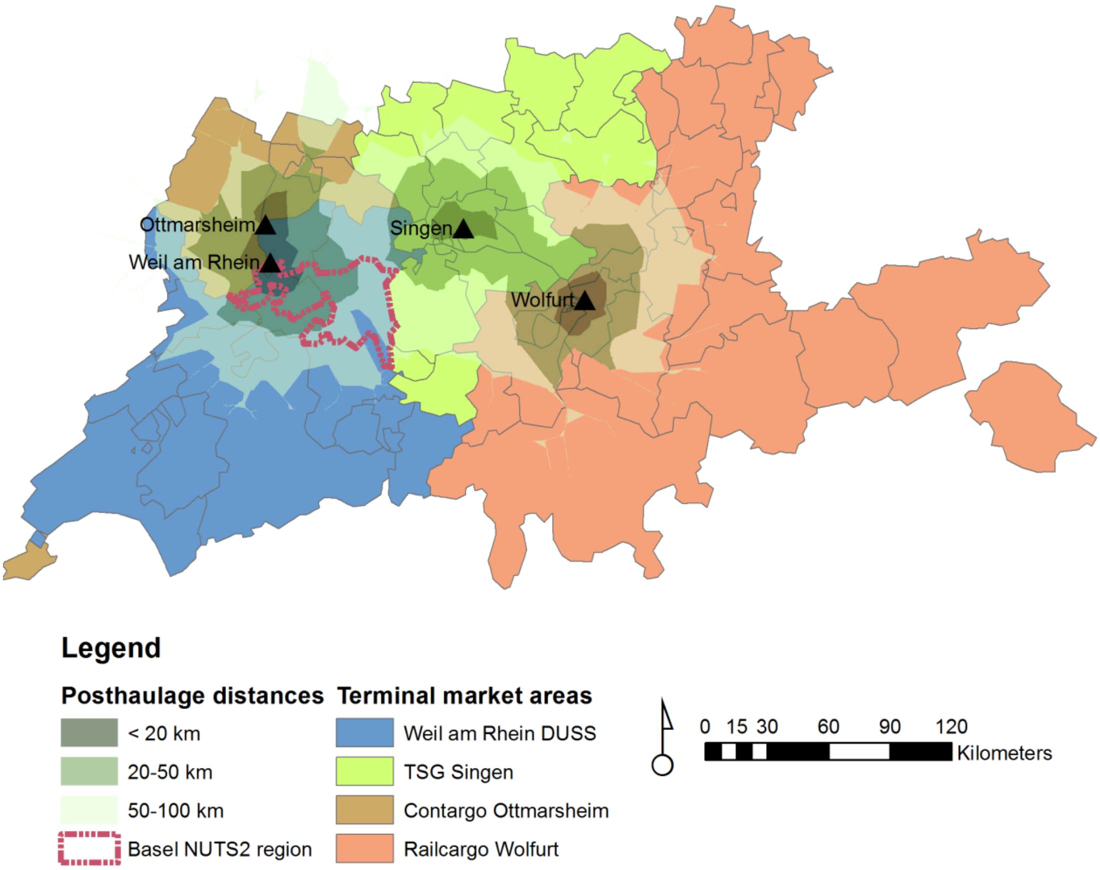
Figure A3.5 Overview of container flows to Switzerland



Conclusions

This chapter presents the Euro Terminal Model, which aims to analyse intermodal rail freight transport in Europe. The model is based on the LAMBIT methodology which is scaled on the Belgian intermodal terminal landscape. Within the framework of Twin hub network, the model is extended to the European level. Another enhancement of the model is related to the integration of a rail cost function. The model compares transport alternatives based on the current market prices for each transport mode. Taking the Twin hub pilot trains into account, the model handles two cases (Slaskie and Basel). The results of the Euro Terminal Model prove that intermodal rail transport has potential compared to unimodal road transport due to longer distances where rail transport is competitive. One of the major findings of the analysis is a break-even distance of at least 384 kilometres is needed for rail transport to compete with unimodal road transport. The model also indicated which terminal to use in the hinterland regions.

Figure A3.6 Market area analysis for Basel region



As the LAMBIT methodology work continues, additional improvements of the analyses can be realised in the future. For methodological reason, an initial and vital perspective for further research focuses on the assumptions of the model. Apart from the transport prices, other modal choice criteria are also important, such as reliability, speed, frequency, safety and customer satisfaction. These other modal choice variables can also be incorporated in the model. A second development can be achieved with using weighted transport distances in the model. Finally extended post-haulage limitation can changed with forward, backward post-haulage options.

Appendix 4

Evolution of pilot networks during the run of the Twin hub project

(E. Kreutzberger, R. Konings)

Introduction

The design of the pilot network was no easy task, witnessed by the continuous change of pilot networks. This appendix describes the design (planning) process, gives an overview of the pilot networks agreed on and explains the major reasons for the changes.

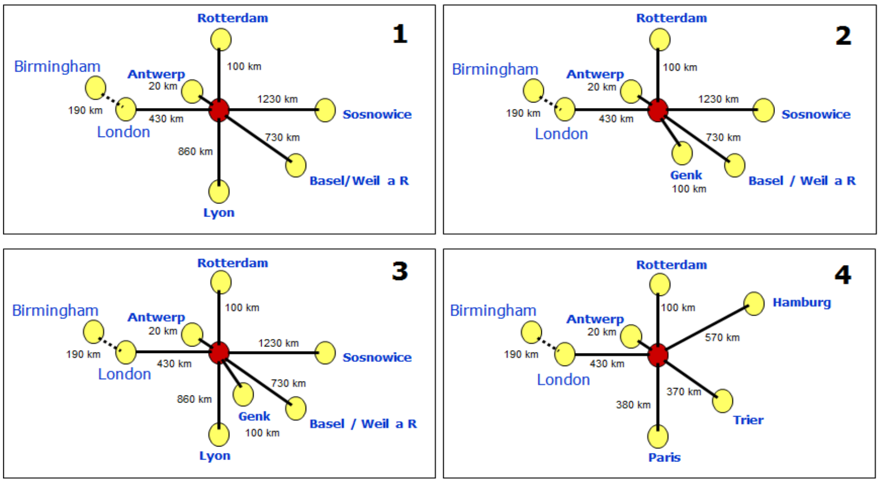
Steps to design the pilot network

After having identified promising Twin hub regions the project had to decide on connections, in other words:

- to select the inland regions and seaports to access and which begin-and-end terminals (Figure A4.1);
- to decide which rail terminal in a seaport to connect to which inland terminal (Figure A4.2);
- including which hub node to use;
- including which operator will provide which connection (Figure A4.3 A)
- including how the train roundtrips are designed (Figure A4.3 B).

These steps iterated with feasibility calculations.

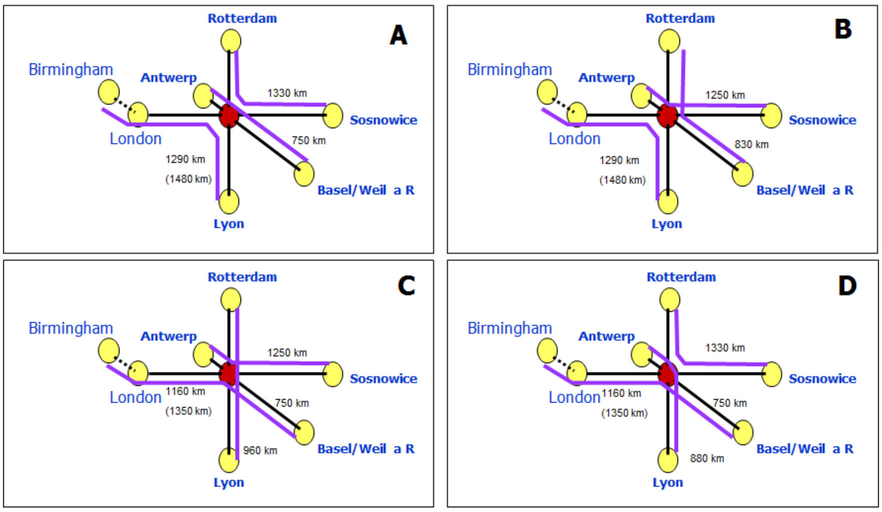
Figure A 4.1 Alternative candidate pilot networks (2012; examples)



The three (to four) rail operators in the project – intentionally and in practice – had the dominant voice in this process, as they are the market specialists recruiting customers and as they are to carry the commercial risk. The other project partners could oppose to or second the proposals of the operators on the basis of network theoretical considerations, like principles of bundling or of operational efficiency. The port authorities had additional arguments, especially which connections strengthen the position of the seaport.

The design is an iterative process between the rail operators in the pilot, supported by research activities. The planning cooperation between different rail operators in this project was a difficult task, mainly for the following reasons.

Figure A 4.2 Alternative combinations of spokes to train services (2012; examples)



Pilot networks in 2012

In the first phase of the planning, during 2012, the pilot networks contained the spokes to the inland terminals Lyon, Genk, Geleen, and to Poland (e.g. Slaskie), Basel and UK (e.g. London or West Midlands). Lyon, Poland and UK because of the analysis of promising regions and customers in picture, Genk en Geleen rather because of concrete market opportunities of interest for the UK spoke, Basel because of the convincement of a rail operator in the project. Lyon was also in picture because a French operator, at that time a candidate project partner to substitute an out dropping firm, was in search for better ways to bundle its flows between Rotterdam and Antwerp on the one side and Lyon on the other side. Its hub for this bundling at that moment was Duisburg in Germany, implying a rather large detour. The Twin hub network allowed streamlining the firm's bundling of Lyon flows. Unfortunately, the operator had already invested into hub infrastructure in Duisburg. Instead of betting on two horses, the firm in 2013 withdrew from the Twin hub project. In 2013, also Genk and Geleen were abandoned from the pilot network.

A special feature in some 2012 pilot networks was a shuttle connecting Antwerp and Rotterdam. As the distance between Basel-Rotterdam via Antwerp was too long to cover by a roundtrip of 3 days, the operator on the Basel-spoke sympathised with splitting off the Antwerp-Rotterdam segment. The train between Antwerp and Rotterdam would have a frequency of 6 services per week, serving the Basel and southeast German trains which each would run 3 times a week. Such operational model would lead to full trainloads and a good roundtrip productivity on all parts of the southeastern pilot spokes (Figure A4.3 B). The Antwerp-Rotterdam train was designed to visit several rail terminals in Rotterdam.

The pilot network 2013

In 2012 it became clear that the UK train preferably ends in London. The benefit of London was that continental instead of UK wagons could be used. The continental ones have a larger gauge and therefore are more efficient. At London load units could be transhipped to and from domestic UK trains (Figure A4.3 A). The terminal London Barking would fulfil a hub function with rail-rail transhipment besides functioning as begin-and-end terminal with rail-road transhipment. The hub function would be a secondary one next to Antwerp still being the pilot's primary hub

Figure A 4.3 Assigning the connections to rail operators and designing the train roundtrips and exchanges

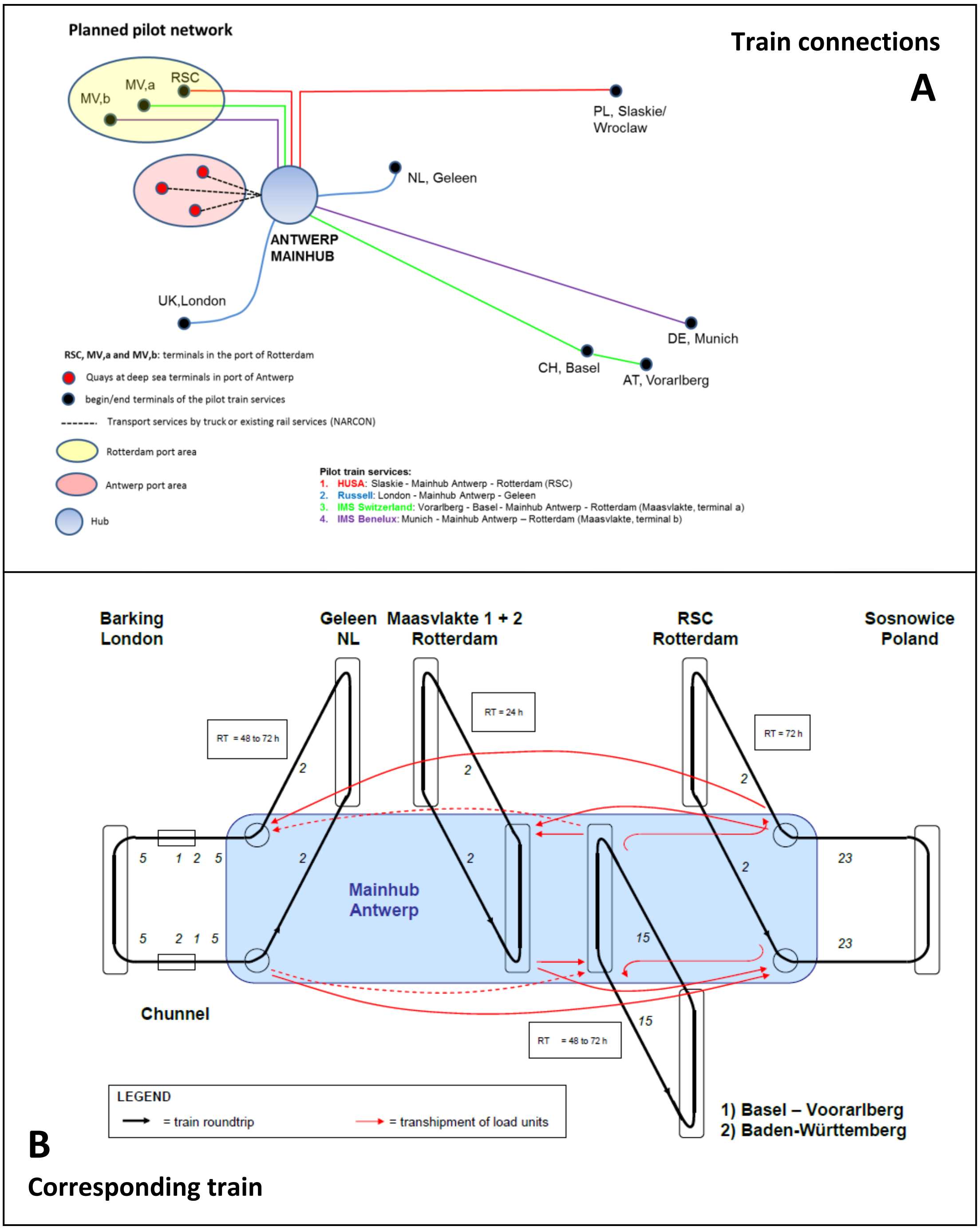
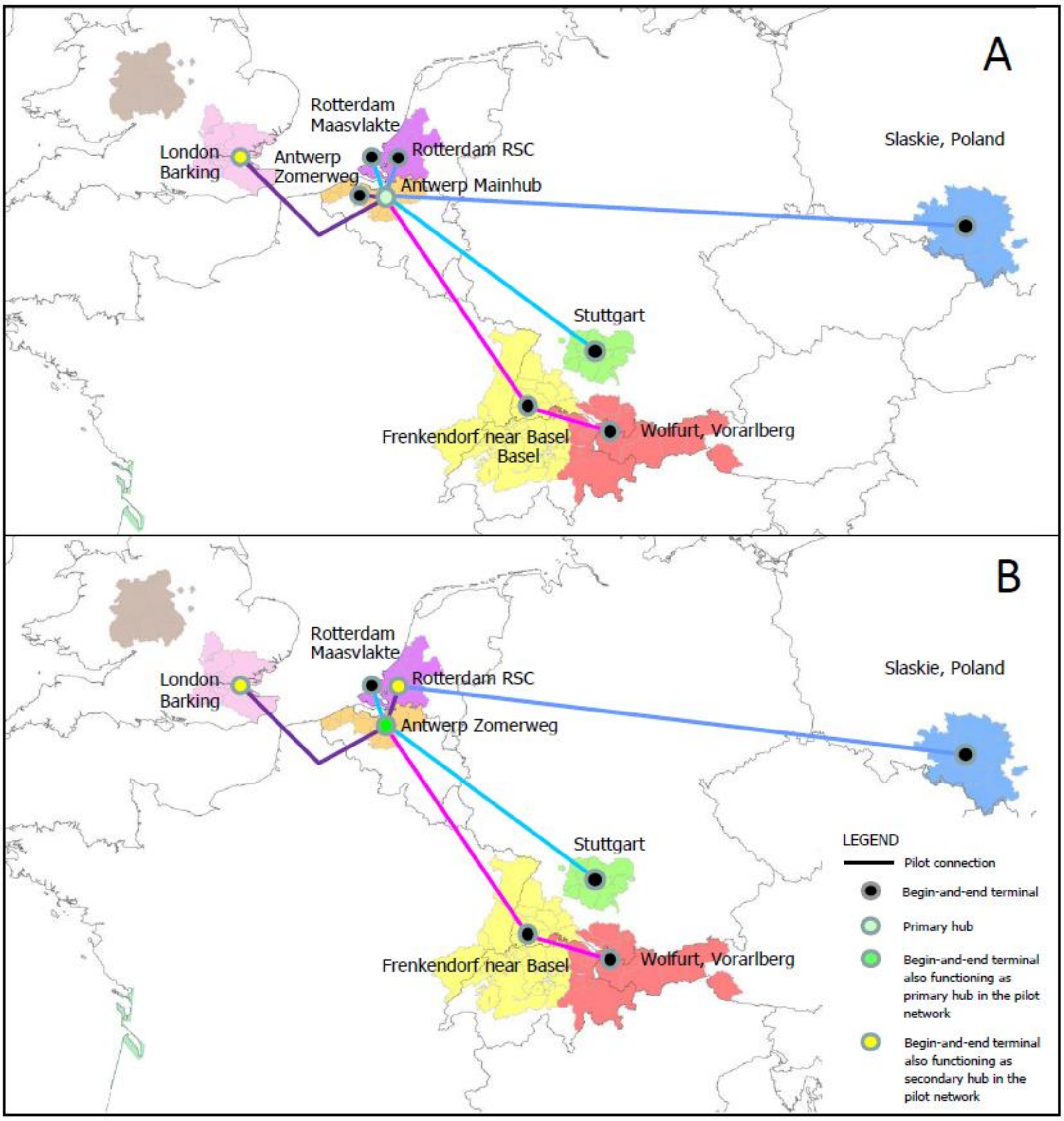


Figure A4.4 A shows one of the first pilot networks receiving commitment by all the project. An important consideration was that the Mainhub terminal in Antwerp would fulfil the hub function, a logic solution given the geographical orientation of the pilot (with other spokes it could have been Rotterdam). Another argument was the scarce

Figure A4.4 The Twin hub pilot network as discussed (A) and agreed on (B) in 2013



capacity or other limitations at Rotterdam terminals making also the Dutch rail operator in the pilot preferring to bundle at Antwerp. This network of all pilot options clearly was the closest to the initial conceptual intentions of Twin hub network.

The pilot network in 2014

In 2013 the Dutch rail operator signing for the Poland spoke changed priorities, not willing to serve Poland anymore and eventually leaving the project. In the same period the UK operator, aware of the potential of UK-Poland flows because of the project's analysis and because of new Polish customers, started cooperating with a another Dutch, a project-external operator. This firm was already running a train between Rotterdam and Poznan (middle Poland). Given the size of the UK-Poland flows the external operator started planning a second rail connection Rotterdam-Poland.[42] This external operator would not except a detour due to visiting a hub in Antwerp. The UK- and Poland spoke would then need to be interconnected at Rotterdam (Figure A4.4 B). In other words, part of the hub function would then be deconcentrated from Antwerp to Rotterdam. Antwerp would nevertheless remain being the pilot's primary hub where most pilot trains would mutually exchange load units.

The shift of hub functions to Rotterdam became even more logic when end of 2013 the Belgian government announced to end the subsidy to the malfunctioning domestic intermodal rail network NARCON. In this network trains from different rail terminals in the seaport met at the Mainhub to mutually exchange load units and then move on to a Belgian inland terminal. This network was the main user of the Mainhub. The network had once been invented to decongest the ringway around Antwerp. The subsidy to the network (see Macharis and Pekin, 2009) was therefore accepted by the European Commission. A consequence of stopping the subsidy was that (most of) the network would come to an end implying a (temporal) shutdown of the Mainhub (Mackor, 2013). The operator of the Mainhub, moved the hub function to a multimodal (rail, road, deepsea) rail terminal in the seaport, Zomerweg (Figure A4.4 B). This terminal is less easy for trains to reach from outside the port and less equipped for efficient rail-rail transhipment, but has the advantage of being reachable by barge. The rail legs between the hub and the maritime rail terminals would largely be substituted by truck and barge.

In the final pilot network agreed on in 2014 (A4.5 A), the number of spokes in the south-eastern corridor was reduced to one, namely Basel (and further). In addition, trains on the UK spoke would not visit Antwerp, but Dourges. The Twin hub logic of these features is explained in Section 6.6. Dourges with regard to the change of planning requires further explanation.

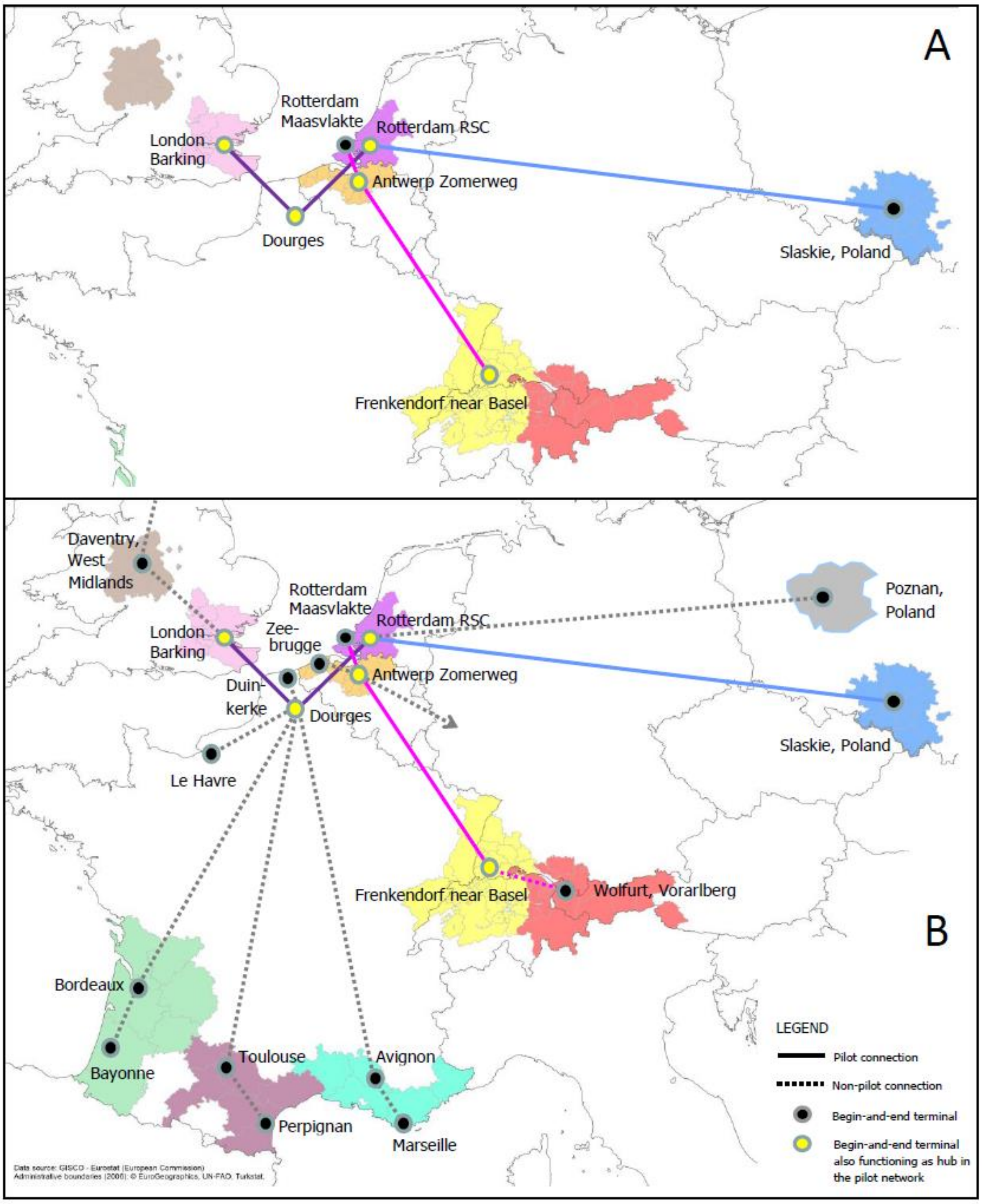
The UK operator in the project planning a London-Rotterdam connection, became interested in letting his train visit Dourges instead of Antwerp. Antwerp provides more flows for the pilot network than Dourges, but the UK operator believed Dourges to be more beneficial to the firm and the embedment of his terminal London Barking in the European rail network.
Dourges could be justified from the Twin hub logic, potentially serving as a third hub for the consolidation of rail flows of the seaports in the Duinkerke-Amsterdam range or even in the Le Havre-Amsterdam range. Only the scale of transport in this third hub region is smaller.

The implication for the pilot was a further decentralization of the hub function, now from Antwerp to Dourges (Figure A4.5 A). In fact, the pilot network now had no primary and secondary hub anymore, but instead several hubs used by different spokes.

[42] The idea was to first establish a shortsea-rail connection UK-Poland while preparing a train connection UK-Rotterdam. Eventually, on the rather short term, the all-rail connection should substitute the shortsea-rail connection.

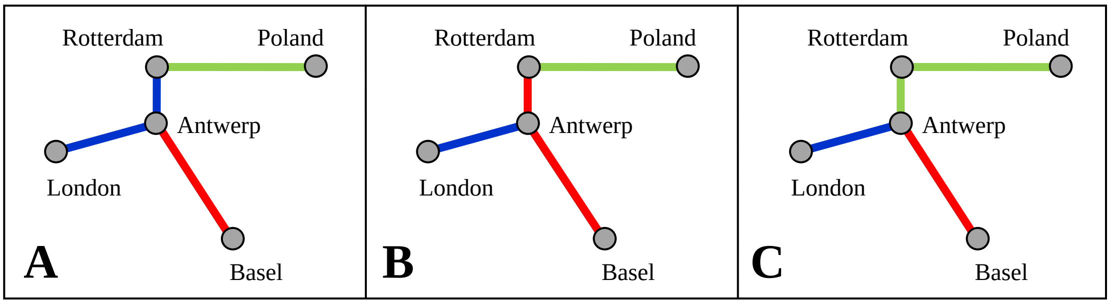
In Section 6.6 we conclude the pilot network 2014 hardly resembles a Twin hub network, but that, at second sight, the Twin hub logic still is very manifest. Only, it is more present between pilot and non-pilot trains (Figure A4.5 B) than only between pilot trains. This shift from intra-pilot train exchange to exchange between pilot and non-pilot trains had not been anticipated when planning the project, but is not illogical, given the way the operators had been selected for the project. The result actually resembles a further, like second phase of the development of the Twin hub network, in which the network is already larger than in the initially planned pilot phase.

Figure A4.5 The Twin hub pilot network agreed on in 2014, without (A) and with (B) attached non-pilot connections



The connection Antwerp-Rotterdam, benefits for all, costs for one
The balance of efforts and benefits to run trains are not the same on the different spokes. Sometimes the balance is influenced by the network design. The most striking example in the network design process of the Twin hub pilot was and is the connection Antwerp-Rotterdam. It extends the roundtrip of a train service by about one day, mainly because of the relative long handling times at seaport rail terminals. The UK roundtrip (London-Antwerp to Rotterdam) is extended from 2 to 3 days, the Basel (Basel-Antwerp to Rotterdam) roundtrip and the Poland roundtrip (Rotterdam-Poland to Antwerp) each from 3 to 4 days. The extensions mean that less roundtrips can take place per week[43] making the train service cost more per kilometre. Should the UK, Basel or Poland train carry this burden (Figure A4.6), while all spokes benefit from the interaction in the form of increasing the size of the trainloads? If all spokes were commercialised by one firm, all costs and benefits appear on one account. Now the costs and benefits of each spoke are on different accounts. The firm connecting Rotterdam and Antwerp is likely to have higher train costs per kilometre. The service may still be profitable, but the manager of the operator has more to justify to the operator's owner. All cumulates in no operator wanting to sign for connecting Antwerp and Rotterdam.[44]

Figure A4.6 Which spoke interconnects Antwerp and Rotterdam?



Rail operators involved in the planning of the pilot
The operators in picture were:

1) Spoke 1:
    a. Interferryboats (=IFB; draft Application Form);[45]
    b. TX Logistik substituting IFB (Application form and published State aid notification);[46]

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[43] UK: 2 instead of 3, Basel or Poland 1 instead of 2.
[44] There is however one exception to this hindering argumentation, resulting in an encouraging argumentation. Wherever a roundtrip normally takes 3 days (like Basel-Antwerp or Rotterdam-Poland), one of the two roundtrips per week will have 4 days. The fourth day serves to provide periodical train departure and arrival times and is hardly spent productively. This fourth day could be spent to connect Antwerp and Rotterdam. Only the additional distance would increase the train costs, while the time costs are already paid. The trains on the Poland and Basel spokes together could connect Antwerp and Rotterdam under these favourable conditions up to the frequency of 4 services per week. There are also other roundtrip situations with time reserves which could be used for connecting Antwerp and Rotterdam. Dependent on the frequency they may even be present for the UK-trains.
[45] Withdrawal because of the entry of a new corridor manager having other priorities;

   c. IFB substituting TX Logistik (draft Request for Changes to INTERREG and published State aid notification);[47]
   d. RailLink/Greenmodal substituting TX Logistik (approval by general manager of Raillink and member of the board of the holding Greenmodal; application meeting together with the firm at JTS in Lille);[48]
   e. IMS Belgium substituting TX Logistik (Request for Changes 2014 to INTERREG and published State aid notification);
2) Spoke 2: Russell (Application form and published State aid notification);
3) Spoke 3:
   a. ACTS/Husa (Application form and published State aid notification);[49]
   b. CTL stating to be highly interested in Twin hub and participating in several meetings together with the project and the port authorities Rotterdam and Antwerp, but not concretising this interest;
   c. ERS substituting ACTS/HUSA (Request for changes 2014 to INTERREG and published State aid notification).

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46 Motivation for becoming a partner in the project: wanting to serve the “west” (e.g. Antwerp and Rotterdam) next to the “north” (e.g. Bremen and Hamburg) seaports and therefor to provide new rail services. Withdrawal because the firm bet on two horses. Next to becoming partner in the project the firm engaged a Dutch agent to develop new train services from and to Rotterdam . The agent at that time had other priorities.

47 Withdrawal because the firm became one “with economic problems” in the sense of European definitions. Such firm may not receive other funding. Also the firm, restructuring its organisation and activities, abandoned experimental network innovations.

48 Motivation for becoming a partner in the project: wanting to bundle Antwerp and Rotterdam to and from France (Lyon, Marseille) flows more efficiently. At that moment the firm bundled the part of these flows via Duisburg! The reason for withdrawal was a perception mistake, as the firm had also invested into terminal infrastructure in Duisburg. The manager could not justify such investment if the bundling would take place in Antwerp or Rotterdam without using the Duisburg terminal. The project has not checked the correctness of the investment statements.

49 Withdrawal because the rail operator of HUSA, Shuttlewise, would not agree on participating in the pilot. This contrasted to the fact that the owner of HUSA had signed the partnership agreement etc. This process was accompanied by sequential exchange of two HUSA managers, the contact persons in the Twin hub project.

Appendix 5
Explanation of calculation of train times and costs and of the Rail Cost model (RACOM)

(E. Kreutzberger)

RACOM primarily refers to the costs of trunk trains. In overview tables (not in this appendix) also the costs of local trains from/to/through the terminals (sometimes referred to as the last mile) are included.

Intermodal rail operators in practice apply a range of business models concerning locomotives, wagons and train drivers. 1) Large(r) or specialised firms may have own vehicles and drivers. Specialised is to say that they also offer their traction and wagon services to other operators. Widespread are the alternatives to either 2) lease locomotives and have own drivers and wagons, 3) to outsource all traction (locomotives and drivers) but still to own the wagons, or 4) to lease locomotives and wagons, but to run them with own drivers. In the most extreme alternative 5) the traction is outsourced and also the wagons are leased. If the trains are continuously in business, meaning that at most times they are involved in a train roundtrip, any outsourcing model is relative expensive, compared to model 1. But keeping the resources in operation continuously during a longer period apparently is so challenging, that many intermodal rail operators apply one or other outsourcing model. The lease rates seem to incorporate an insurance functionality, letting the leasers pay for non-active periods of e.g. locomotives. Rail operators also lease equipment or use external traction in order to reduce the amount of (pre)financing. In the pilot the models 1 (ERS) and 5 (Russell and IMS Belgium) are applied. The cost modelling for this report is based on model 4, featuring some of all and also in line with some operators who were in picture (potential substitute partners and operators for the pilot) during the run of the project.

The train costs used in the analysis to analyse the competitiveness of door-to-door rail services are the ones reported by the rail operators to the project. The project has compared these with own calculations. The calculated costs are slightly lower in all cases, the difference featured by $\boldsymbol{C}_{\boldsymbol{a}}$ (Equation 1). In the difference per kilometre $\underline{c}_{\boldsymbol{a}}$ (Equation 3) the difference of all pilot routes can be compared.

The calculated total train costs are the sum of locomotive and wagons (lease) costs, and of the costs of drivers, energy, infrastructure use, monitoring and a surplus representing overhead, profit and taxes. The lease costs including capital and maintenance costs and drivers costs to its customers, the rail operators, work[50] as fixed costs. The energy, infrastructure and monitoring costs are variable ones.

The lease costs per train service are the annual lease costs divided by the number of vehicle business weeks per year, the number of periodical roundtrips per week $n_{PRT\,week}$ and 2 journeys (the back and forth journey in a roundtrip, each being a transport service; Equations 4 and 5).

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50 In model 1 the maintenance costs consist of fixed and variable maintenance costs.

The drivers costs per service (Equation 6) are the drivers costs per hour $\mathbb{C}_{dr} / \mathbb{T}_{dr}$, $\mathbb{T}_{dr}$ in hours, times the number working hours per diver service $T_{dr\ service}$, times the number of drivers per service or driver hours per service hour $n_{dr\ service}$.
The infrastructure or monitoring costs per service (Equations 7 and 9) are the product of kilometric costs and the service distance. The energy costs per service (Equation 8) are the energy costs per ton-km times the gross train weight (train, load units, loads) times the service distance.
The surplus is calculated as a rate on top of the sum of fixed and variable costs.

The train costs per load unit are the total train costs divided by the number of load units (Equation 2).
The approach in Equations 4 and 5 defines all time of a year except the time for maintenance as business time. The annual business time is also the sum of all periodical roundtrip times. All time of a periodical roundtrip is business time. It consists of the operational roundtrip time, describing all time spent on links and nodes including waiting time for operational reasons (Equation 10) and the waiting time due to periodical departure and arrival times of trains at their begin-and-end terminals. Periodical departure time means that a train departs at same times of a departure day (analogue with arrival times). A periodical roundtrip therefore lasts 24 hours[51] or a multiple of this, dependent on the distance, the smallest multiple above the operational roundtrip time (Equation 11). If a periodical roundtrip lasts 3 days, a week allows to realise two of these implying a periodical roundtrip time of 6 days. A third roundtrip in the same week is impossible (Equation 12). However, the vehicle costs also need to be earned back on the 7th day. The periodical roundtrip time relevant to calculate trains costs $T_{P\ RT\ week}$ then is 3,5 days (Equation 13). In practice there may be a roundtrip of 3 days and another one of 4 days, the latter covering the weekend. The time used to calculate the train costs per train service T_{SE} is the half of $T_{P\ RT\ week}$ (Equation 14) as the roundtrips in the pilot consist of a back and a forth journey and as these are more or less symmetric.

Variables

$\mathbb{L}$	= Annual lease costs (including maintenance costs)
L	= Lease costs per train service (including maintenance costs)
$\mathbb{C}$	= Annual costs per train
C	= Train costs per train service
$\underline{C}$	= Train costs per kilometre of a train service
$\underline{\underline{C}}$	= Train costs per ton kilometre of a train service
c	= Train costs per load unit per train service
s	= Surplus rate (because of overhead, profit, taxes), e.g. 1,2
d	= Distance
W	= Weight of a train including empty and loaded load units
$\mathbb{n}$	= Annual number
n	= Number
$\underline{T}$	= Productive time per year = number of business hours per year
T	= Time of train

[51] For roundtrips with night-jump departure and arrival times of a train the periodical roundtrip time is 48 hours. Train services between maritime seaports and inland terminals often nevertheless have periodical roundtrip times of only 24 hours, of the operational roundtrip times allows such. The reason is that night-jump departure and arrival times are required at the inland terminal only rather than at both ends of the service.

Suffix indices

dr	= driver
i	= infrastructure
e	= energy
m	= monitoring
l	= of the locomotive
w	= of a wagon
lu	= of a load unit
O	= operational
P	= periodical
RT	= roundtrip
SE	= service
week	= per week
bw	= business week
link	= link
node	= node

Combinations of variables and suffix indices (exceptionally explained as combination)

C_a	= Additional integral train costs = difference between reported train costs ("prices") and calculated train costs
$n_{dr\ service}$	= Number of driver hours per service hour (e.g. = 1,7)

Equations

$$C = (L_l + L_w + C_{dr} + C_i + C_e + C_m) * s + C_a \tag{1}$$

$$c = C / n_{lu} \tag{2}$$

$$\underline{C}_a = C_a / d \tag{3}$$

$$L_l = \mathbb{C}_l / \mathbb{n}_{bw\,l} / n_{PRT\,week} / 2 \tag{4}$$

$$L_w = \mathbb{C}_w / \mathbb{n}_{bw\,w} / n_{PRT\,week} / 2 \tag{5}$$

$$C_{dr} = \mathbb{C}_{dr} / \mathbb{T}_{dr} * T_{dr\ service} * n_{dr\ service} \tag{6}$$

$$C_i = \underline{C}_i * d \tag{7}$$

$$C_e = \underline{\underline{C}}_e * d * W \tag{8}$$

$$C_m = \underline{C}_m * d \tag{9}$$

$$T_{O\,RT} = T_{O\ links\ RT} + T_{O\ nodes\ RT} \tag{10}$$

$$T_{P\,RT} = \text{smallest multiple of 24 hours above } T_{O\,RT} \tag{11}$$

$$n_{P\,RT\,week} * T_{P\,RT} \leq T_{week} \tag{12}$$

$$T_{P\,RT\,week} = T_{P\,RT} + (T_{week} - \sum T_{P\,RT}) / n_{PRT\,week} \tag{13}$$

$$T_{SE} = T_{P\,RT\,week} / 2 \tag{14}$$

The most important parameters in the cost modelling are shown in the following table.

	Variable	Parameter/value	
Lease costs locomotive	$\mathbb{L}_{l}$	550.000	Euro/year
Lease costs wagons *	$\mathbb{L}_{w} * n_{lu}$	300.000	Euro/year
Number of vehicle business weeks per year	$n_{bw\,l} = n_{bw\,w}$	48	Weeks/year
Annual costs employer per driver	$\mathbb{C}_{dr}$	105.000	Euro/year
Annual number of working hours of a driver	$\mathbb{T}_{dr}$	1.920	Hours/year
Number of driver (hour)s per service (hours)	$n_{dr\,service}$	1 for $n_{P\,RT} \leq 24$ h, 1,4 otherwise	Factor
Infrastructure costs	$\underline{C}_{i}$	2,29	Euro per train-km
Energy costs	$\underline{\underline{C}}_{e}$	0,0016	Euro per ton-km of a train
Monitoring costs	$\underline{C}_{m}$	0,170445	Euro per train-km
Surplus	s	1,2	Factor

* Wagon part = 600m long

Appendix 6
Backgrounds to the competitiveness of all-rail chains between Daventry and London on the one side and Rotterdam and Antwerp on the other side towards short sea chains

UK - Rotterdam

Train costs per rpundtrip		All costs per LU	West-Midl.	West-Midl.	London	London
(euro)		(euro)	Rdam	Rdam	Rdam	Rdam
			train	shortsea	train	shortsea
		PPH Daventry	210			
		Terminal Daventry	30			
		Final mile Daventry	9			
via 22 euro / train-km	3.080	Train Daventry - London	96			
		PPH London			180	
Train roundtrip	32.600	Train London - Rdam	509		509	
Final mile Barking	600	Final mile London	9		9	
Final mile Antwerp	1.000	Final mail Antwerp	16		16	
Final mile RSC	500	Final mile Rdam	8		8	
Lifts	3.640	Terminal London	30		30	
		Terminal Rdam	40		40	
Administration	267	Administration	4	4	4	4
Roundtrip slot costs	1.519	Roundtrip costs	24		24	
		Truck UK		510		260
		Shortsea incl. terminals		250		250
		Transfer Rdam		25		25
		Terminal Rdam		40		40
		Total	985	829	820	579
Etica per roundtrip	3.000	Etica	47		47	
		Total incl. Etica	**939**	**829**	**773**	**579**
Cost reduction per service	1.600	If F=4 or 6/week instead of 3	50		50	
train London-Rotterdam		Most beneficial total	**889**	**829**	**723**	**579**

UK - Antwerp

Train costs per rpundtrip		All costs per LU	West-Midl.	West-Midl.	London	London
(euro)		(euro)	Antwerp	Antwerp	Antwerp	Antwerp
			train	shortsea	train	shortsea
		PPH Daventry	210			
		Terminal Daventry	30			
		Final mile Daventry	9			
via 22 euro / train-km	3.080	Train Daventry - London	96			
		PPH London			180	
Train roundtrip	32.600	Train London - Awerp	**428**		**428**	
Final mile Barking	600	Final mile London	9		9	
Final mile Antwerp	1.000	Final mail Antwerp	16		16	
Final mile RSC	500	Final mile Awerp	8		8	
Lifts	3.640	Terminal London	30		30	
		Terminal Awerp	40		40	
Administration	267	Administration	4	4	4	4
Roundtrip slot costs	1.519	Roundtrip costs	24		24	
		Truck UK		510		260
		Shortsea incl. terminals		250		250
		Transfer Awerp		25		25
		Terminal Awerp		40		40
100km, 1,1 euro/truck-km,		Road Zeebrugge - Antwerp		**129**		**129**
85% with retour load *						
		Total	**904**	**958**	**739**	**708**
Minus A	3.000		47		47	
Etica per roundtrip		Etica	**857**	**958**	**692**	**708**
		Total incl. Etica				
Minus B	1.600	If F=4 or 6/week instead of 3	50		50	
Less train costs because frequency			854	958	689	708
Minus A and B			97		97	
		Most beneficial total	**760**	**958**	**595**	**708**

* Rather more, e.g. on the basis of 1,7 euro/km, given the short distance.

2 = Differences with regard to Rotterdam.

= all-rail is cheaper than the reference chain.

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