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Complementarity and substitutability among adjacent gateway ports

Theo E Notteboom
Institute of Transport and Maritime Management Antwerp (ITMMA), University of Antwerp, Keizerstraat 64, B-2000 Antwerp, Belgium; e-mail: theo.notteboom@ua.ac.be
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Abstract. The author considers complementarity and substitutability among container ports located in a single gateway region. The level of substitutability from a shipping line's perspective is assessed by means of an analysis of revealed preferences in the port-calling pattern of vessels deployed on different trade routes. The author also identifies and analyzes the factors contributing to levels of port substitutability as perceived by shipping lines. The methodology is applied to the Rhine – Scheldt Delta, a major European multiport gateway region. It is demonstrated that the large load centres in the Delta are increasingly acting as substitutes, while each of the smaller container ports functions more as a complement to one of the large load centres.

1 Introduction

Fleming and Hayuth (1994) and Van Klink and Van den Berg (1998) defined gateways as nodal points where intercontinental transport flows are transshipped to continental areas, and vice versa. Many world ports act as gateways to extensive inland logistics networks; often there is more than one gateway giving access to a specific region. Table 1 provides a list of the world's main multiport gateway regions with regard to container handling. The share of traffic in total container throughput tends to differ quite significantly between the gateway regions; a number of multiport gateway regions feature a high density of port terminals in a small geographical space, whereas other regions cover larger areas.

Condensed regions with a high concentration of gateway ports are prime study objects for the analysis of the nature of port terminal competition. The often complex linkages in the governance and management of port areas and terminals within the same multiport gateway region have received a great deal of attention in academic literature. Wang and Slack (2000) analyzed the complex port interactions in the fast-growing Pearl River Delta; Cullinane et al (2005) discussed competition between Shanghai and Ningbo in the Yangtze Delta. Several chapters in Cullinane and Song's (2007) book are dedicated to competition, cooperation, and governance issues in the Yangtze Delta, the Pearl River Delta, Singapore and Tanjung Pelepas, and the South Korean twin hub Busan and Gwangyang. In the port-governance book edited by Brooks and Cullinane (2006) the situation in many European gateways is discussed. Charlier (1996) and Notteboom (2007) paid special attention to the Benelux seaport system; Marti (1988) zoomed in on the Pacific load centres on the North American West Coast, and Starr (1994) and Shashikumar (1999) discussed port dynamics in North American gateways along the East Coast. Although all of these and other authors discuss port competition, cooperation, and interrelations between gateway ports situated in specific geographical regions, none really assesses the extent to which the load centres on the same region act as substitutes for each other.

In this paper I aim to unravel the functional interdependency between the container ports in a single multiport gateway region with the aim of analyzing the degree of complementarity and substitutability among the ports and terminals concerned.

Table 1. The ranking of major world container-handling regions, and their throughput in million TEU (twenty-foot equivalent units) based on respective port data.

Cluster	Container ports	Distance (km)[a]	1985		1995		2000		2004		2006		2007[b]	
			throughput	rank	throughput	rank	throughput	rank	throughput	rank	throughput	rank	throughput	rank
Pearl River Delta	Hong Kong, Shenzhen, Guangzhou, Zhongzhan, Jiuzhou	130	2.34	3	13.74	1	24.26	1	40.16	1	49.95	1	55.26	1
Malacca Straits	Singapore, Port Klang, Tanjung Pelepas	340	1.70	6	12.98	2	20.66	2	30.41	2	35.88	2	na[c]	2
Yangtze River Delta	Shanghai, Ningbo	180	0.20	8	1.69	8	6.51	7	18.56	3	28.78	3	35.81	3
Rhine–Scheldt Delta	Rotterdam, Antwerp, Zeebrugge, Amsterdam	105	4.20	1	7.74	3	11.38	3	15.59	4	18.67	4	21.64	4
Bohai Bay	Dalian, Qingdao, Tianjin	350	0.20	9	1.68	9	4.84	9	11.16	7	16.86	5	20.45	5
San Pedro Bay	Los Angeles, Long Beach	10	2.25	4	5.40	4	9.48	4	13.10	5	15.76	6	na	
Korean Twin Hub	Busan, Gwangyang	135	1.16	7	4.50	6	8.22	5	12.81	6	13.79	7	na	
Helgoland Bay	Hamburg, Bremerhaven, Wilhelmshaven	95	2.15	5	4.41	7	7.03	6	10.52	8	13.31	8	15.21	
Tokyo Bay	Tokyo, Yokohama, Shimizu	50	2.46	2	5.16	5	5.63	8	6.59	9	na	9	na	

[a] Farthest distance between competing ports in the cluster.
[b] Based on growth throughput in the first nine months.
[c] na—not available.

The case study discusses the Rhine–Scheldt Delta region, one of the main container-port regions in the world. Two research questions are posed: (a) to what extent do shipping lines consider the gateway ports in the Rhine–Scheldt Delta area as substitutes or complements? and (b) what factors explain the complementarity or substitutability among the load centres concerned? In the first part of the paper I provide a theoretical discussion on the concepts of substitutes and complements and on the contributory factors. In the second part I provide an answer to research question (a). Based on revealed preferences of shipping lines in terms of the choice of ports of call, the extent to which the gateways within the Rhine–Scheldt Delta act as complements or substitutes is demonstrated. In the last part of the paper I tackle research question (b) by analyzing the factors which contribute to perceived substitutability or complementarity between container ports in the Rhine–Scheldt Delta.

2 A methodological note on complements and substitutes

2.1 Methodological approaches

The concepts of complements and substitutes are documented extensively in microeconomic theory (see, for example, Varian, 1993). From a neoclassical perspective, it can be argued that two load centres in the same multiport gateway region are *perfect substitutes* for a port user if that user is willing to substitute one load centre for another at a constant rate. Two load centres are *perfect complements* if they are always 'consumed' together in fixed proportions by a port user.

One possible method of analyzing the degree of substitutability between ports is by starting from the demand curve and determining the cross-price elasticity between two ports: elevated cross elasticities indicate a high degree of substitutability. In the case of complements, the cross elasticity of demand will be negative. The demand-curve approach has been applied in a number of studies of port pricing (eg Haralambides et al, 2001), and the determination of the demand curve in social cost–benefit analyses related to port projects (eg Teurelincx et al, 1997).

In this paper I follow an alternative approach, determining the level of substitutability from a shipping line's perspective by analyzing the revealed preferences in terms of vessel calling patterns. Here, two load centres are *complements* if a container vessel deployed by a shipping line on a specific loop will either call at both load centres or at none of them. Two load centres are *substitutes* for a specific trade if a vessel only calls at one or the other load centre. Before engaging in this sort of analysis it is of prime importance to ascertain that the ports considered are not independent, that is, calls in one port must have an effect (either substitutional or complementary) on the other ports in the region.

2.2 Complementarity, substitutability, and liner-service design

A high degree of substitutability between individual load centres is associated with fierce interport competition. In contrast, a high level of complementarity would create an environment in which mutual coordination prevails—at least for the container market segment considered.

The application of these concepts in a seaport context requires insight into how shipping lines design their liner services. Figure 1 demonstrates the complexity of liner-service design. The first step in the design of a regular container service consists of the identification of the markets to be served. Once the trade route for the (new) liner service has been identified, the service planner will have to make decisions at three operational tiers:

(1) the service frequency (including the fixed days/hours of the week for departures/arrivals), the vessel capacity, the fleet mix, and the vessel speed;

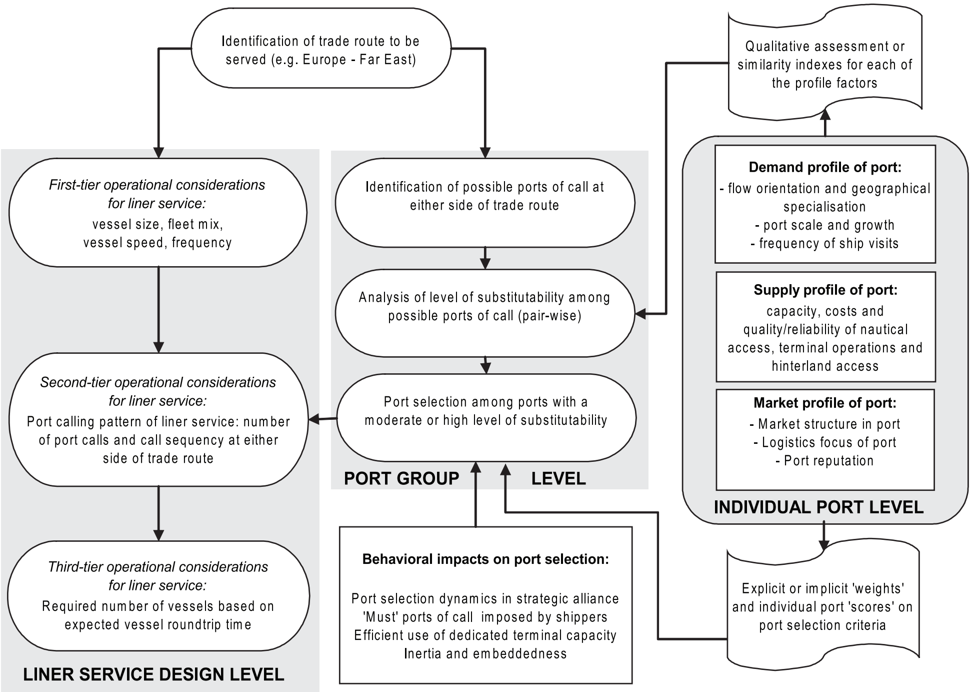

Figure 1. A conceptual model of liner-service design by a shipping line, including the relationships between liner-service design, port substitutability, and port selection.

(2) the number and order of port calls per roundtrip; and
(3) the required number of vessels, derived from the desired frequency and the vessel roundtrip time (function of route length, vessel speed, and total port time).
These three tiers in liner-service design are highly interrelated.

The level of substitutability among adjacent load centres plays an essential role in the decision-making process at the second tier in the planning process. Hence, when deciding on a port-calling pattern, shipping lines explicitly or implicitly follow a two-stage process. In a first step they define those ports which serve as substitutes within the particular geographical market to be served, based on some sort of qualitative or quantitative assessment of the level of substitutability or similarity among ports (see the text box at the top right corner of figure 1). In a second step, service planners will select a port among each set of load centres which shows a moderate or high level of substitutability.

In both these stages, service planners will compare ports on a wide range of factors and criteria. Based on the combined results of a number of empirical studies on port selection from the perspective of shipping lines (Barros and Athanassiou, 2004; Chou et al, 2003; Guy and Urli, 2006; Lirn et al, 2004; Malchow and Kanafani, 2001; Murphy and Daley, 1994; Murphy et al, 1992; Nir et al, 2003; Song and Yeo, 2004; Tiwari et al, 2003), three distinctive groups of factors can be distinguished:
(a) The demand profile of the port includes factors such as the flow orientation of the port towards the foreland and the hinterland, the scale and growth of the port, and the connectivity of the port within wider maritime networks. Two ports with largely overlapping forelands and hinterlands typically are perceived as substitutes. Moreover, the degree of substitutability is likely to be higher among load centres of comparable scale and function than among load centres of widely diverging scales and with different functions.

(b) The supply profile of the port concerns the availability, cost, quality, and reliability of the nautical access, container terminals, and hinterland access. Based on these characteristics, shipping lines explicitly or implicitly allocate a distinctive supply profile to each of the ports concerned. If two adjacent seaports show a similar supply profile, then the level of substitutability tends to be high.
(c) The market profile of the port: this is a group of factors which includes factors such as the cargo-control characteristics, the structure of the terminal-operating business within the port, and presence of logistics activities in the port, the logistics focus of the port, and the port reputation.

Load centres can never be considered perfect substitutes or perfect complements. Differences among ports in terms of demand profile, supply profile, and/or market profile make load centres imperfect substitutes or imperfect complements to shipping lines.

The demand, supply, and market-profile factors outlined above will also guide the port-selection process among each set of substitutable load centres. In theory, shipping lines could base their final decision on a (weighted) combination of scores on each of the selection factors (Lam, 2007). In practice, the interplay of factors contributing to the final port choice is not transparent to outsiders.

Even in the case where a shipping line has a decision-support system for rational port choice, the final outcome might not always correspond to a modelled optimum solution. Hence, port choice is influenced by factors that go beyond the traditional port-selection criteria (see the text box on behavioural impacts in figure 1). If a shipping line is part of a strategic alliance, port choice is subject to negotiations among the alliance members and can deviate from the choice of one particular member (Slack et al, 2002). Important shippers might impose a certain port of call on a shipping line leading to bounded rationality in port choice. A shipping line might possess a dedicated terminal facility in one of the load centres of a multiport gateway region and might therefore be inclined to send more ships to that facility because of considerations of optimal use (Cariou, 2001). A last example relates to the role of inertia and local embeddedness in port choice. Carriers might remain with a specific port because they assume that the mental efforts and costs involved in making changes in their network design would outweigh the costs associated with the current nonoptimal solution.

Notwithstanding the complexity associated with the port-selection process as outlined above, the analysis of the level of substitutability or complementarity among load centres remains a key element in understanding shipping lines' decisions regarding port-calling patterns.

3 Analyzing complementarity and substitutability based on liner-service networks

In this section I deal with the outcome of second-tier operational decisions in liner-service design by examining the actual port-selection behaviour of container shipping lines, primarily for the loops between Europe and the Far East and the loops in service in the transatlantic trade. The Rhine–Scheldt Delta area serves as case study. This multiport gateway region accommodates a large concentration of seaports with a total maritime throughput of 710 million tonnes (18% of the total port throughput in the European Union) and a container throughput of 18.7 million TEU (twenty-foot equivalent units) in 2006—about 23% of the European total (see figure 2). Only Rotterdam, Antwerp, Zeebrugge, and more recently also Amsterdam (a group abbreviated in this paper to the 'ZARA ports') are involved in the deep-sea container business.

Table 2 provides an overview of the liner services on the Northern Europe–US/Canada trade routes and the Northern Europe–Far East trade routes in February

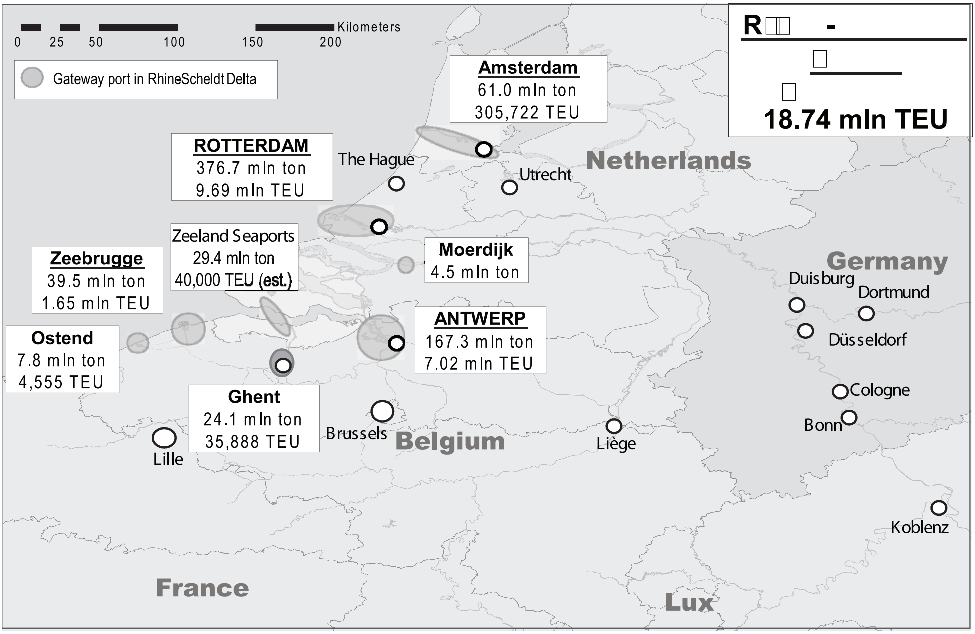

Figure 2. Total cargo throughput in millions of tonnes (mln ton) and container throughput in TEU (twenty-foot equivalent units) in the gateway ports of the Rhine – Scheldt Delta (figures for 2006).

2006 (data were obtained from the carriers). Many liner services are operated by more than one carrier in a framework of slot-chartering agreements or a strategic alliance, for example the New World Alliance, or the Grand Alliance. In table 2 such liner services were counted once in order to avoid possible overlaps in service networks of different carriers.

Table 2 includes 130 North European port calls per week: 35 loops for the Far East trade (an average of 3.7 different ports of call per loop) and 88 calls per week in 26 loops for the transatlantic services (3.4 different ports of call per loop). Rotterdam and Hamburg dominate the Far East scene, followed by Antwerp and Felixstowe. Rotterdam accommodates some 22% of all European port calls per week and is integrated in 83% of all loops on the Europe – Far East trade. Antwerp has the strongest position in the Europe – US/Canada trade. The ZARA ports represent more than one third of all calls per week in North European container ports. All the loops on both trade routes call at one or more ports in this multiport gateway region, as is confirmed by table 3. Most mainline operators running services to/from the continent stick to line-bundling itineraries with calls scheduled in each of the main markets—Benelux, Germany, France, and the United Kingdom. Notwithstanding the diversity in calling patterns on the observed routes, carriers select three to five regional load centres per loop with partly overlapping hinterlands. The figures indicate that the ports in the Rhine – Scheldt Delta are not independent of each other with respect to liner-service patterns.

Figure 3 provides an overview of the significance of the load centres of the Rhine – Scheldt Delta in loops to and from the US/Canada and the Far East. First, shipping lines never integrate three load centres together in one loop; hence, the relations between a number of port pairs must show some degree of substitutability.

Table 2. Service loops on the Europe – Far East and Europe – US/Canada trade routes February 2006.

Port [a]	Share in port calls per week (%)	Share in slot capacity per week (%)	Loops calling at port (%)
Europe – US/Canada			
Antwerp	19.3	18.4	65.4
Rotterdam	15.9	15.9	53.8
Bremen	15.9	17.4	53.8
Le Havre	12.5	13.0	42.3
Hamburg	9.1	9.2	30.8
Felixstowe	6.8	8.4	23.1
Thamesport	6.8	7.4	23.1
Liverpool	5.7	3.9	19.2
Tilbury	4.5	3.9	15.4
Dunkirk	2.3	1.7	7.7
Southampton	1.1	1.0	3.8
Zeebrugge	0.0	0.0	0.0
Amsterdam	0.0	0.0	0.0
Gothenburg	0.0	0.0	0.0
Aarhus	0.0	0.0	0.0
Total	100	100	
ZARA ports	35.2	34.3	
Europe – Far East			
Rotterdam	22.3	22.7	82.9
Hamburg	21.5	20.7	80.0
Antwerp	10.8	9.8	40.0
Felixstowe	10.0	10.3	37.1
Southampton	9.2	9.4	34.3
Le Havre	8.5	8.6	31.4
Bremen	6.2	6.7	22.9
Zeebrugge	4.6	4.3	17.1
Thamesport	3.1	2.7	11.4
Amsterdam	1.5	1.5	5.7
Dunkirk	0.8	1.0	2.9
Gothenburg	0.8	1.1	2.9
Aarhus	0.8	1.1	2.9
Liverpool	0.0	0.0	0.0
Tilbury	0.0	0.0	0.0
Total	100	100	
ZARA ports	39.2	38.4	

[a] Ports shown in boldface are ZARA cluster ports.

Table 3. Configuration of loops in terms of ports of call in specific countries, February 2006.

Configuration of port rotation in North Europe	Percentage of all loops	
	Europe – Far East	Europe – US/Canada
1 Benelux port of call, 1 German port of call, 1 UK port of call	34.3	23.1
2 Benelux ports of call, 1 German port of call, 1 UK port of call	14.3	7.7
1 Benelux port of call, 1 German port, 1 UK port, and 1 French port	14.3	7.7
2 Benelux ports of call, 1 German port, 1 UK port, and 1 French port	11.4	11.5
Other configurations	25.7	50.0
Total number of loops	35	26

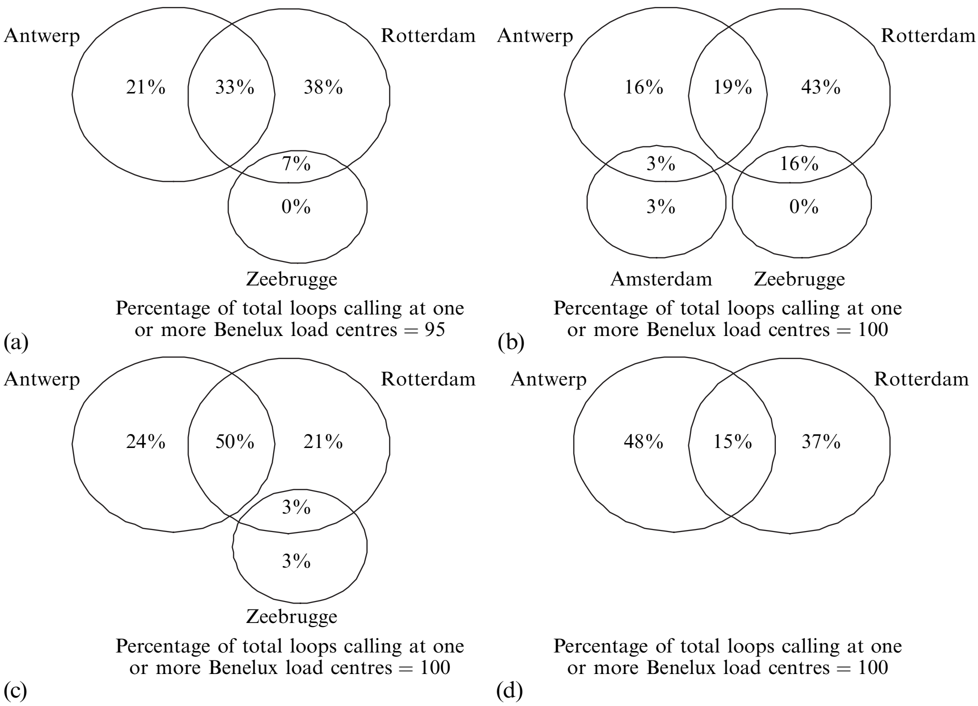

Figure 3. Ports of call in the Rhine – Scheldt Delta—percentage of number of total loops: Northern Europe – Far East (a) October 1998, (b) February 2006; Northern Europe – US/Canada (c) October 1998, (d) February 2006.

Second, Zeebrugge and Antwerp never appear together in the same loop, whereas Zeebrugge and Rotterdam occasionally serve as ports of calls within the same liner service; this suggests that Zeebrugge and Antwerp are treated primarily as substitutes in deep-sea liner shipping. This is striking as it is often assumed that a high degree of complementarity exists between the Flemish load centres in terms of location (coastal port versus upstream port) and overall traffic structure (short-sea versus deep-sea routes). The alleged substitute nature of the Zeebrugge – Antwerp combination needs to be put into the right perspective. I demonstrate in section 4.6 below that a substantial part of container flows discharged or loaded in Zeebrugge originates from, or ends up in, the port of Antwerp.

Third, shipping lines tend to consider Antwerp and Rotterdam more and more as substitutes in their liner services, not as complements. In 1998, one third of all Far East services, and half of all loops to the US/Canada, called at both ports within the same loop. Today, these figures have dropped to 19% and 15%, respectively.

Fourth, carriers' behaviour reveals that in 2006, 85% of the loops on the Europe – US/Canada route call at just one terminal in the Delta, compared with 47% in 1998. On the Asian trade routes, this figure changed only slightly, from 60% in 1998 to 62% in 2006. The remarkable difference between the two trades is explained by the relatively recent emergence of Zeebrugge and Amsterdam on the Europe – Far East scene. These ports are typically 'consumed' together with Rotterdam and Antwerp, respectively.

The relationship between Rotterdam and Antwerp as depicted in table 4 is particularly interesting. Except for South American cargoes, the share of loops featuring joint calls in both Antwerp and Rotterdam is fairly low. A more detailed analysis of the liner services revealed that calls in Antwerp and Rotterdam within the same loop are

Table 4. Rotterdam and Antwerp as ports of call in intercontinental loops, February 2006.

Europe to/from	Calls in both ports (%)	Only call in Antwerp (%)	Only call in Rotterdam (%)	No calls in Antwerp or Rotterdam (%)	All loops (%)
US/Canada	14.8	48.1	37.1	0.0	100.0
Far East	18.9	18.9	59.5	2.7	100.0
South America	53.3	13.3	26.7	6.7	100.0
Middle East—India/ Pakistan	25.0	37.5	37.5	0.0	100.0
Africa	6.7	79.9	6.7	6.7	100.0
Overall	21.6	36.3	39.2	2.9	100.0

more likely to occur in cases of diagonal and secondary trade routes. Moreover, joint calls occasionally occur as part of the entry strategy of a shipping line new to the trade route. In this last case, the joint-call option is often followed by a rationalization in calling patterns towards only one port of call in the Delta per loop. The calling-pattern behaviour of strategic alliances is more complex: some alliances, such as the Grand Alliance and the New World Alliance, operate several loops on the Europe–Far East trade; each loop does not necessarily call at the same load centres in the Delta. Such arrangements allow for maximum market coverage.

Next to the number of port calls, the port-calling order is of importance in understanding the level of substitutability among load centres. If the port of loading is the last port of call on the maritime line-bundling service, and the port of discharge the first port of call, then transit time is minimized (Lago et al, 2001). In practice, shipping lines' decisions on the order of ports of call is influenced by many commercial and operational determinants, including the cargo-generating effect of the port (outgoing cargo), the distribution of container origins and destinations over the hinterland, the berth-allocation profile of a port, the nautical access, the time constraints of the round voyages, and so on. A port which regularly acts as a last port of loading or a first port of discharge in a liner-service schedule has, in principle, more chance of achieving a higher deep-sea call efficiency ratio (that is, the ratio between the total TEU discharged and loaded in the port and the two-way vessel capacity) compared with rival ports which are in the middle of the loop.

A more detailed analysis of the loops on the transatlantic and Europe–Far East trades reveals that Antwerp often appears as first port of call on the transatlantic trade, but seldom on the Far East trade. Shipping lines hardly ever position Rotterdam as last port of call for Asian cargoes. This confirms the general market perception concerning the Asian trade: Rotterdam has a strong inbound-cargo profile, whereas Antwerp possesses a rather strong cargo-generating effect for export flows. The resulting imbalance in the accommodation of inbound and outbound flows points to some degree of complementarity among these large load centres, notwithstanding the existence of fierce interport competition.

4 Factors contributing to functional complementarity and substitutability in the Rhine–Scheldt Delta

In the previous section I demonstrated the extent to which the ports in the Rhine–Scheldt Delta function as complements or substitutes in the liner-service schedules for deep-sea container carriers. In line with figure 1, in this section I provide a more detailed analysis of the factors contributing to perceived levels of substitutability between the container ports in the Delta. Table 5 provides an overview of some of

Table 5. Main factors contributing to perceived substitutability/complementarity between container ports in the Delta.

	Rotterdam	Antwerp	Zeebrugge	Amsterdam	Flushing
Demand profile					
Scale and growth					
TEU[a] throughout 2006	9.69 million	7.02 million	1.65 million	0.304 million	40 000
Growth 1990–2006 in TEU (%)	6.02 million (164%)	5.47 million (353%)	1.32 million (394%)	0.24 million (341%)	
Growth 2000–2006 in TEU (%)	3.4 million (54%)	2.9 million (72%)	0.69 million (71%)	0.25 million (475%)	
Foreland and Hinterland orientation					
Strong foreland regions	Far East/intra-Europe	US/Canada/Africa/ Near East	intra-Europe/Asia	limited	
Strong hinterland regions	Northwest Europe (focus east)	Northwest Europe (focus southeast)	Belgium, UK, France, Germany	Netherlands, Germany	
Exchanges over land in Delta	strong with Antwerp	strong with Rotterdam and Zeebrugge	strong with Antwerp	some with Rotterdam	
Supply profile					
Room for expansion					
Major terminal projects	Euromax: 2008 Maasvlakte 2: 2013/2014	Deurganckdock: open since Summer 2005	APM terminals since Summer 2006	Ceres Paragon: first vessel 2005	WCT: 2010 (?) other terminals
Location and nautical access					
Location	coastal port	upstream river port	coastal port	canal port	estuary port
Diversion distance (nautical miles)	5	60	10	20	15
Maximum draft (m)	16.7	14.7 (tide dependent) 11.5 (tide independent)	15	13	15.5 (tide dependent) 13 (tide independent)
Market profile					
Market structure terminal operating business	ECT (Hutchison PH) APM terminals	PSA—HNN Antwerp Gateway[b] MSC/PSA—HNN	PSA—HNN/CMA CGM APM terminals	NYK (member Grand Alliance)	PSA–HNN (?) (future terminal)
Cargo control	40% carrier haulage 60% merchant haulage large shippers and carriers	25% carrier haulage 75% merchant haulage strong forwarding industry	B/L Antwerp only 35% deep-sea	cacao trade	local group
Distribution activities in port	3 distriparks	extensive (strong 'naties')	limited	limited	limited
Stuffing and stripping in port	15% of containers	< 5%	< 5%	na	local cargo

[a] TEU—twenty-foot equivalent units. [b] Antwerp Gateway: DP World/CMA CGM/Cosco/ZIM/Duisport.

the main factors that are at play from the perspective of a shipping line. In the following sections, each of the factors is analyzed in more detail.

4.1 Scale of the port

Large ports typically have a more comprehensive offer of sailings, which adds to the frequency offered to the market. The higher critical mass also makes it easier to set up and sustain frequent and dedicated multimodal transport solutions by barge or rail to hinterland destinations. The scale of Rotterdam and Antwerp is considerably larger than that of any other port in the Delta. This means that a smaller port will have difficulty in developing itself as a fully fledged substitute to either Antwerp or Rotterdam.

4.2 Expansion plans and opportunities

New capacity plans imply growth potential, which is important to attract new customers and to retain existing ones. New terminals are constructed to secure and further strengthen the role of the ports as gateways. The port of Rotterdam has developed ambitious infrastructure plans to build a second Maasvlakte on land reclaimed from the sea; the first terminal should be open for business by 2013–14. In the meantime, the new Euromax-terminal (northern part of the current Maasvlakte) is expected to start operations in 2008. The Belgian port of Antwerp opened the first phase of a tidal container dock on the left bank of the river Scheldt in 2005. When fully operational, the tidal dock will reach an annual capacity of at least 7 million TEU. These examples shows that the large load centres in the area are responding to carriers' demand for new container-terminal capacity.

The container growth potential in the Delta has attracted nonhub ports into the container business. Since the spring of 2006 APM Terminals has operated a container terminal on the Albert II Dock South in Zeebrugge. In recent years, shipping line CMA–CGM has developed Zeebrugge as a major hub in its network. The limited cargo-generation capacity of the port, and its less favourable barge connections for serving the German hinterland, are some of the weaknesses of Zeebrugge. The Dutch seaport of Amsterdam opened its Ceres Paragon terminal in 2001, with its distinctive state-of-the-art handling system based on an indented berth. The aggressive policy of the current owner, NYK, in pursuing clients has resulted in the Grand Alliance including Ceres Paragon among its ports of call since 2005. The Dutch seaport of Flushing is eager to start large-scale container operations on the Westerscheldt Container Terminal (WCT), which as a quay length of about 2 km, and other, more local, terminal operators (Verbrugge Terminals, Sea-Invest/Zuidnatie) have developed detailed plans to open container terminals in the port's dock system. The realization of the WCT remains uncertain.

In the coming ten years, it is expected that new terminals will add about 21 million TEU of capacity, without taking into account the upgrading of existing terminals in the ports concerned. About 70% of this new capacity will be located in the existing large load centres. Consequently, additional terminal supply in small and medium-sized ports is expected to have a moderate impact on port hierarchy. Smaller ports in the Rhine–Scheldt Delta try to project themselves as substitutes for the large load centres of Antwerp and Rotterdam. The recent relative success of Amsterdam and Zeebrugge in the Far East trade is an indication, but earlier it was found that shipping lines always use these ports together with an established load centre. Smaller container ports will have a difficult time challenging the established large load centres. New entrants in the container-handling market typically meet the requirements for maritime accessibility and terminal layout, and might be well positioned to accommodate a part of the sea–sea transshipment flows—particularly in relation to the Asian trade.

However, they will have to tackle major issues, including: the vicious cycle in setting up hinterland networks; their general lack of experience in stakeholder-related procedures linked to large terminal projects, and their lower cargo-generating and cargo-binding potential (typically a result of their lack of associated forwarder and agent networks). For the time being, smaller container ports will continue to act mainly as complements to Antwerp and/or Rotterdam, not as fully fledged substitutes.

4.3 Location and nautical access

Zeebrugge and Rotterdam are coastal ports. Antwerp is a river port, situated upstream on the river Scheldt at a distance of some 80 km from the North Sea. This upstream location has some advantages and some disadvantages. Container vessels can sail to the economic markets in the hinterland, and thus face lower costs in hinterland transportation. However, the access from the sea is more expensive and time-costly (Baird, 1996; Notteboom et al, 1997). In Antwerp, vessels with a draft of 11.5 m can enter the port independent of the tide, and a new deepening programme will further improve the nautical access to accommodate 13.1 m-draft vessels independent of the tide. However, the largest container vessels will still need to take into account some tidal-window restrictions. The container terminals on Rotterdam's Maasvlakte can accommodate the largest container vessels at any time. The maritime access to Zeebrugge allows ships with a draft of up to 16.5 m, independent of tide. The location characteristics of the ports are reflected to some extent in the nature of the container flows by sea and over land that pass through the ports.

4.4 Traffic volumes—foreland orientation

Historically, Antwerp has had a very strong market position on the North Atlantic and north–south routes to Africa. Antwerp's market share in the Delta with respect to the US/Canada trade has increased from 43% in 1992, to 48% in 1998, and 60% in 2005. The competitive position of Antwerp for transshipment activities in relation to the African continent increased from a share of 55% in 1992 to 68% in 1998, and nearly 75% in 2005. However, both trades show only modest growth in themselves. Antwerp has lost market share in its strongholds of the Central and South American routes but the port has succeeded in increasing its importance in almost all other non-European trades, with the Near East and Middle East routes being the most remarkable growth areas (from 64% in 1998 to 78% in 2005, and from 30% to 47%, respectively).

Zeebrugge has undergone a major traffic reorientation since 1998. This Belgian coastal port has lost its position on trades to the Americas and Africa, but has gained significant increases in market share on the Middle East and Far East trade routes.

Rotterdam remains the dominant player in the fast-growing intra-European and Far East markets. One of the factors in the success of Rotterdam in attracting Far East trade relates to its excellent nautical access for the very large vessels that are deployed on this route (unit capacities in the range of 6500 to 13 000 TEU). Short-sea and feeder flows remain relatively modest in the upstream port of Antwerp, partly because of its upstream location. However, efforts to stimulate coastal shipping have resulted in an increase of intra-European container traffic, from 259 000 TEU in 1994 (12% of Antwerp's container throughput) to 1.28 million TEU in 2005 (19%). Also, in Zeebrugge feeder and short-sea traffic, mainly to the United Kingdom, has gained in importance and now represents some 70% of the port's container volume (up from 62% in 1998).

The aforementioned findings are confirmed when orientation indices are applied (table 6). The 'orientation index' compares the share of a given traffic route in a port's container throughput to the share of that route in the total port traffic in the Delta. A value of 1 indicates equality of actual values and the expected, 'fair share', amount.

Table 6. Orientation indices for Rotterdam, Antwerp, and Zeebrugge.

Route	Rotterdam			Antwerp			Zeebrugge		
	1998	2002	2005	1998	2002	2005	1998	2002	2005
Africa	0.43	0.37	0.43	2.10	2.03	1.96	0.85	0.12	0.30
North America	0.74	0.82	0.74	1.47	1.44	1.58	1.07	0.04	0.02
Central and South America	0.76	0.92	0.95	1.57	1.27	1.25	0.46	0.19	0.15
Near East	0.54	0.42	0.33	1.97	1.89	2.06	0.53	0.52	0.47
Middle East	1.16	1.26	0.94	0.91	0.79	1.25	0.08	0.29	0.26
Far East	1.30	1.35	1.34	0.62	0.61	0.58	0.24	0.58	0.77
Europe	1.15	1.09	1.12	0.54	0.61	0.60	1.78	2.34	2.09

Values above 1 for a given traffic show greater than average volumes, and values below 1 point to lower volumes than the 'fair share' (Charlier, 1991; Hoare, 1986). The overrepresentation of Rotterdam in the Near East trade is declining, whereas significant gains have been achieved on its traffic flows to and from Central and South America. Antwerp remains overrepresented in Africa, North America, and the Near East, but has difficulties in improving its weaker position on the Far East and European trades. Zeebrugge has lost its presence on the African and North American trades, but the Far East has gained in significance.

The overall picture is quite diverse: in some geographical market segments specialization is taking place, with one port acting as the dominant player; in other segments, the positions of the load centres are converging.

4.5 Traffic volumes—hinterland orientation

Table 7 provides an overview of the relative shares of different hinterland regions in total hinterland container transport for the main load centres of the Rhine–Scheldt Delta. The local hinterland remains very important: about 38% of Rotterdam's hinterland cargo remains in the Netherlands. For the Belgian ports of Antwerp and Zeebrugge, Belgian cargo amounts to around half of the total container flows to the hinterland. Both Belgium and the Netherlands are home to high concentrations of European distribution centres. Containers are emptied in a European-distribution centre near the ports; after reconditioning or some value-added activities, the once-containerized cargo is distributed all over Europe via conventional trucks. Maritime container volumes remain local, but the goods have a much larger European coverage in the end.

Table 7. Hinterland container flows in Rotterdam, Antwerp, and Zeebrugge (based on twenty-foot equivalent units in 2004).

	Germany	Holland	Belgium	France	Other [a]	Total
Market share (%)						
Rotterdam	16.3	20.8	9.8	1.0	6.4	54.3
Antwerp	8.8	5.3	19.9	4.1	2.9	41.1
Zeebrugge	0.7	0.4	2.3	1.0	0.2	4.6
Total	25.8	26.5	32.0	6.1	9.5	100.00
Orientation indices						
Rotterdam	1.16	1.44	0.56	0.29	1.24	
Antwerp	0.83	0.49	1.51	1.66	0.74	
Zeebrugge	0.57	0.34	1.58	3.48	0.45	

[a] Mainly Italy, Switzerland, Austria, Central Europe.

Germany is the most important transit hinterland for the ports of Antwerp and Rotterdam; and about half of the German transit is concentrated in the region Nordrhein – Westfalen (demonstrating the impact of the Ruhr area). The high orientation index of Rotterdam indicates that this Dutch load centre relies much more on its traffic relations with Germany than does either Antwerp or Zeebrugge. The orientation indices further reveal that Antwerp and Zeebrugge have very strong transit relations with France. Rotterdam is overrepresented in transit flows to and from the other regions, mainly Italy, Central Europe, and the Alpine region (Switzerland and Austria).

The traffic analysis points to some degree of traffic complementarity among the load centres in the Delta. Rotterdam shows a more extensive European hinterland coverage than the Belgian ports, and its orientation is more towards the hinterlands in the East and the more distant hinterlands in the southeast of Europe. Antwerp shows a less extensive hinterland coverage, but relies on its very strong presence on the southeast axis from Belgium, Luxembourg, and northeastern France to the Alpine region.

4.6 Exchanges over land

Large volumes of containers are exchanged over land between the three load centres. The Antwerp – Rotterdam flow by inland barge over the Scheldt – Rhine canal was estimated at some 850 000 TEU in 2005 compared with 560 000 TEU in 1997 (in both directions) of which 30% comprises empty containers. Container-barge traffic in Zeebrugge is very limited. Shuttle trains between Antwerp and Rotterdam transported 285 000 TEU in 2004 compared with 120 000 TEU in 1997. Daily shuttle trains between Zeebrugge and Antwerp generated an additional 131 000 TEU in 2004 (45 000 TEU in 1997).

Antwerp has acquired an important 'dry port' function due to its central location in the Rhine – Scheldt Delta area (Charlier, 1996). Containerized cargo often receives a bill of lading for Antwerp, although the physical handling from deep-sea vessel to land takes place in another port. In practice, this implies that these containers are shuttled to Antwerp terminals. It is estimated that Antwerp generates 30% more container traffic than the port physically handles in its deep-sea terminals.

The substantial container exchanges over land between Rotterdam, Antwerp (the central node), and Zeebrugge point to a certain degree of sea – land complementarity. At the heart of this process lies the tension between the 'ship follows the cargo' argument and the 'cargo follows the ship' argument. Such a tension is typical of multiport gateway regions. The 'ship follows cargo' argument is extremely relevant when a shipping line is trying to capture cargo from the immediate hinterland of a port. However, time constraints in service-network operations and increased pressure on draft conditions of the nautical access to ports are supporting the 'cargo follows ship' argument. Shipping lines are now further stimulating cargo to come to the ship by installing port-equalization systems, in which shippers are compensated for possible cost disadvantages in hinterland transportation towards the coastal ports. Such arrangements make it more difficult for an upstream port to remain a substitute for a large coastal gateway.

4.7 Market structure and linkages between market players

Many of the forwarders, independent liner agencies and stevedoring companies operating in one port of the Delta have set up branch offices in other container ports within the Rhine – Scheldt Delta area. This trend towards private company networks is very evident in the forwarding and liner agency business. About 50% of all Rotterdam-based forwarders have a branch office in Antwerp, and 75% of all shipping lines calling at Rotterdam have liner agencies or partners both in Antwerp and in Rotterdam.

Only ten years ago, local terminal operators dominated the container-handling scene and only Hessenatie and Seaport Terminals operated in more than one Delta port (figure 4). At present, the container-terminal business in the Delta is dominated by four global terminal operators (Singapore-based PSA in Antwerp/Zeebrugge, Dubai-based DP World in Antwerp, APM Terminals in Rotterdam/Zeebrugge, and Hutchison Port Holding of Hong Kong in Rotterdam) and a handful of shipping lines, which have minority shareholdings or are engaged in joint-venture arrangements (for example, CMA-CGM, MSC, and Cosco, to name but a few). For many terminal operators the increasing symbiosis between the port of Antwerp and the port of Zeebrugge may emerge as a parallel with Rotterdam and its Maasvlakte facilities. In the summer of 2007, a consortium led by DP World was granted the concession for the second phase of Maasvlakte 2. This implies that one of the two terminal giants in Antwerp will also have a presence in Rotterdam by 2013. It is too early to assess what impact this development might have on the degree of substitutability between these two ports.

The emergence of network structures on the part of shipping lines and terminal operators will allow them to offer more routing alternatives to their customer base, thereby taking advantage of the cargo-control characteristics of the load centres involved (see table 5). The port of Antwerp features a strong forwarding business, the largest covered storage space in Europe, and relies heavily on merchant haulage for

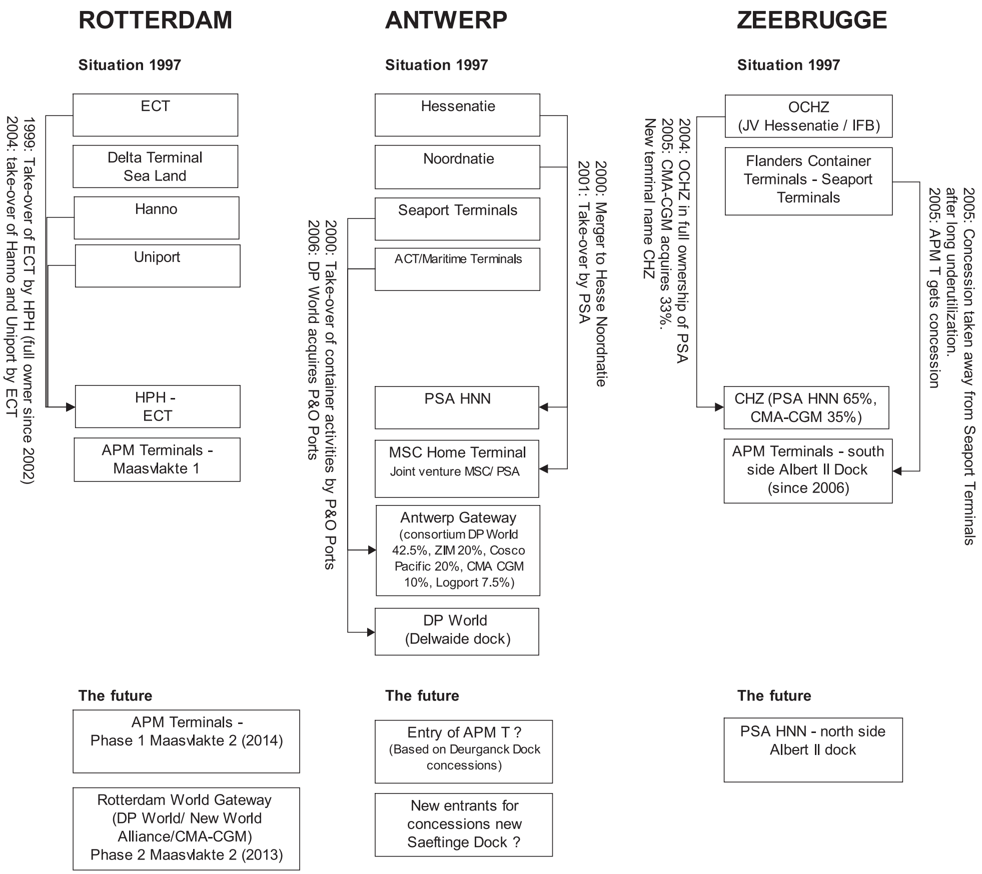

Figure 4. Deep-sea container terminal operators in the Rhine–Scheldt Delta—the situation in 1997 and 2007, and some predictions for the future.

inland distribution. Rotterdam is more of a carrier port, with about half of the storage facilities of Antwerp (most logistics space is offered off-terminal). Table 5 reveals that Zeebrugge and Amsterdam are far less important when it comes to container logistics within the port area. The cargo-control characteristics vary considerably among the ports considered.

5 Measuring the degree of substitutability

In this section I aim to develop a more quantitative framework concerning the factors contributing to the perceived substitutability or complementarity among adjacent load centres from the perspective of a shipping line. Figure 5 depicts a set of measures for the degree of substitutability among adjacent gateway ports. All values range between 0 and 1; a value of close to 0 refers to a port pair showing a high level of similarity on the factor considered. The closer the value approaches unity, the higher the differences among the two container gateways. The mathematical expressions can be found in the appendix.

Figure 5 suggests the following conclusions. First, the port pair Antwerp–Rotterdam shows the highest level of similarity overall and as such can be considered as the load centres of the Rhine–Scheldt Delta with the highest degree of substitutability. The only measures showing a significant divergence between these two main ports relate to diversion distance (coastal port versus upstream port—ΔM_{AB} value of 0.33) and terminal-operators base (that is, both ports have their own distinctive terminal operators, so ΔP_{AB} has a value of 1).

Second, the ports of Rotterdam and Zeebrugge can be classified as quite different ports in terms of scale (see values for ΔS_{AB}, ΔS_{AB}^{F}, and ΔS_{AB}^{H}), the mix of hinterland regions served (ΔD_{AB}^{H}), and the planned terminal-capacity increased (ΔC_{AB}). Zeebrugge and Rotterdam show some similarity in their nautical-access profiles (ΔN_{AB} and ΔM_{AB}) and the mix of foreland regions served (ΔD_{AB}^{F}—both ports have a strong orientation to the intra-European and Europe–Far East routes).

Third, the substitutability between Antwerp and Zeebrugge is complex. Antwerp obviously has a larger scale of terminal operations, and larger scale traffic relations with foreland and hinterland regions. Moreover, this Belgian upstream port has a much

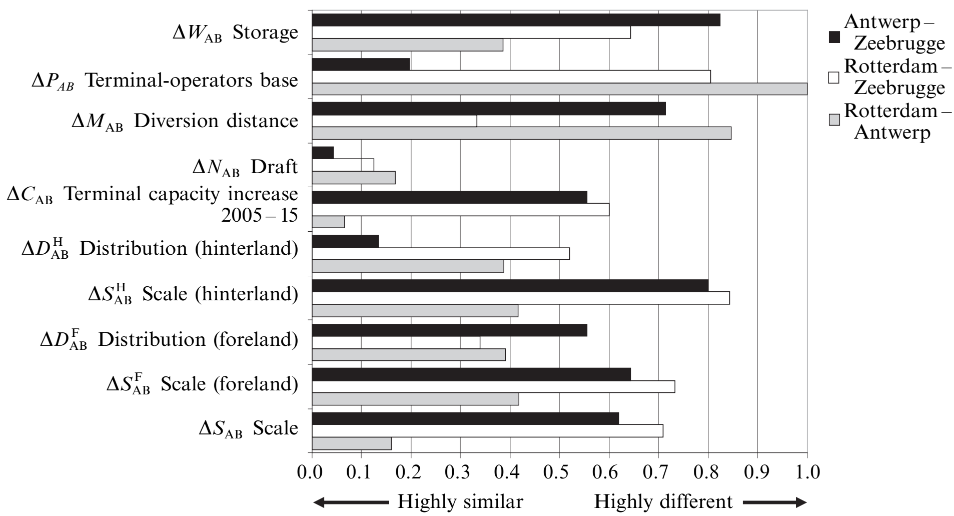

Figure 5. Measures for the degree of substitutability between Antwerp, Rotterdam, and Zeebrugge.

stronger focus on logistics activities and warehousing within the port area (ΔW_{AB} value of 0.83). Whereas Antwerp and Zeebrugge serve more or less the same mix of hinterland regions (ΔD_{AB}^{H} value of 0.134), these Belgian load centres have a very different cargo mix on the maritime side (ΔD_{AB}^{F} value of 0.555, see also section 4.4). The two load centres are fairly different on many of the factors discussed; this might partly explain why global terminal operator PSA holds key positions in the container segment of both of these ports, leading to a very similar terminal-operators base (ΔP_{AB} value of 0.20).

6 Conclusions

In this paper I have analyzed complementarity and substitutability among container ports located in a single gateway region. Revealed preferences in the port-calling pattern of vessels deployed on different trade routes provide a good indicator of the level of substitutability from a shipping line's perspective. I have also identified and analyzed the factors contributing to levels of port substitutability as perceived by shipping lines.

The case study of the Rhine – Scheldt Delta revealed that Rotterdam and Antwerp, the large load centres in the Delta, are increasingly acting as substitutes: but Rotterdam and Antwerp are imperfect substitutes: the positions of these two main ports in the order of ports of call and for various trade routes differ significantly. Smaller container ports function more as complements to one of the large load centres: Zeebrugge and Amsterdam are typically used together with Rotterdam and Antwerp, respectively. None of the shipping lines excludes the Rhine – Scheldt Delta from its liner-service networks, but the decisions of these lines regarding the hierarchy of the ports of call are rarely identical. Most carriers are centralizing their vessel calls in one load centre, although a number of carriers still opt for more than one port of call in the Delta on specific shipping routes to maximize benefit from complementary market elements across load centres. This concentration tendency is somewhat tempered by the 'ship follows cargo' argument: shipping lines are bound to provide the services their customers want in terms of frequency, direct accessibility, and transit times, and these requirements can imply the need for direct calls in more than one port in a gateway region. It is unlikely that there will be a scenario where all leading shipping lines concentrate their deep-sea container business massively in the same gateway port.

Multiple factors contribute to the perceived substitutability or complementarity between container ports in the same gateway region. The quantitative measures of port substitutability revealed that Antwerp – Rotterdam can be classified as the port pair with the highest degree of substitutability in the Delta. Smaller containers ports act as complements to Antwerp or Rotterdam, not as fully fledged substitutes. Some degree of traffic complementarity within the Delta exists at the level of seaborne and inland container flows. Whereas Antwerp and Zeebrugge serve more or less the same mix of hinterland regions, these Belgian load centres have a very different cargo mix on the maritime side. The substantial container exchanges overland between Rotterdam, Antwerp (the central node), and Zeebrugge add to the observed sea – land complementarity. Traffic complementarity between individual load centres can be a strong factor for a gateway region, especially if port policy makers, port managers, and private port companies succeed in combining the specific advantages of each load centre in a constructive manner.

Gateway regions around the world are challenged to cope with the mounting pressures associated with the continued strong growth in maritime container flows. Multiport gateway regions have a competitive edge over regions with only one load centre. Hence, one-load-centre regions offer less routing alternatives to the customer base, and they are likely to be far less able to deal with disruptions and structural changes in logistics-network configurations. The functional interdependencies between load centres of the same multiport gateway region are defined by the interplay of competitive forces emanating from interport substitutability and cooperative forces resulting from complementarity. Although load centres in the same gateway region typically vie for contestable cargo, they are also bound together in a symbiotic relationship by some degree of complementarity. The ability of policy makers, port managers, and market players to manage this balance between substitutability and complementarity effectively distinguishes well-integrated multiport gateway regions from functionally fragmented ones. In this paper I have aimed to provide a better understanding of complementarity and substitutability among adjacent ports. Thus, this paper serves as an input to the rising debate on the functioning, planning, and management of complex gateway regions in the world.

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Appendix

Mathematical expressions for the measures depicted in figure 5

A measure of the difference in scale between ports A and B based on total container throughput in TEU:

$$\Delta S_{\mathrm{AB}} = \frac{|T_{\mathrm{A}} - T_{\mathrm{B}}|}{T_{\mathrm{A}} + T_{\mathrm{B}}}, \qquad 0 \leqslant \Delta S_{\mathrm{AB}} \leqslant 1 \ . \tag{A1}$$

A measure of the difference in scale between ports A and B in relation to the f foreland regions (that is, Africa, North America, Central and South America, Near East, Middle East, Far East, and Europe).

$$\Delta S_{\mathrm{AB}}^{\mathrm{F}} = \frac{\sum_{i=1}^{f} |T_{\mathrm{A}i} - T_{\mathrm{B}i}|}{T_{\mathrm{A}} + T_{\mathrm{B}}}, \qquad 0 \leqslant \Delta S_{\mathrm{AB}}^{\mathrm{F}} \leqslant 1 \ . \tag{A2}$$

A measure of the difference between ports A and B in terms of the mix of f foreland regions served:

$$\Delta D_{\mathrm{AB}}^{\mathrm{F}} = \frac{1}{2}\sum_{i=1}^{f} \left| \frac{T_{\mathrm{A}i}}{\sum_{i=1}^{f} T_{\mathrm{A}i}} - \frac{T_{\mathrm{B}i}}{\sum_{i=1}^{f} T_{\mathrm{B}i}} \right|, \qquad 0 \leqslant \Delta D_{\mathrm{AB}}^{\mathrm{F}} \leqslant 1 \ . \tag{A3}$$

A measure of the difference in scale between ports A and B in relation to the h hinterland regions served:

$$\Delta S_{\mathrm{AB}}^{\mathrm{H}} = \frac{\sum_{j=1}^{h} |T_{\mathrm{A}j} - T_{\mathrm{B}j}|}{T_{\mathrm{A}} + T_{\mathrm{B}}}, \qquad 0 \leqslant \Delta S_{\mathrm{AB}}^{\mathrm{H}} \leqslant 1 \ . \tag{A4}$$

A measure of the difference between ports A and B in terms of the mix of the h hinterland regions served:

$$\Delta D_{AB}^{H} = \frac{1}{2}\sum_{j=1}^{h}\left|\frac{T_{Aj}}{\sum_{j=1}^{h} T_{Aj}} - \frac{T_{Bj}}{\sum_{j=1}^{h} T_{Bj}}\right|, \qquad 0 \leqslant \Delta D_{AB}^{H} \leqslant 1 . \tag{A5}$$

A measure of the difference between ports A and B with respect to the planned terminal capacity increases in the period 2005–15:

$$\Delta C_{AB} = \frac{|C_A - C_B|}{C_A + C_B}, \qquad 0 \leqslant \Delta C_{AB} \leqslant 1 . \tag{A6}$$

A measure of the difference between ports A and B with respect to the tide-independent draft on the nautical access route and along the container terminal quays:

$$\Delta N_{AB} = \frac{|N_A - N_A|}{N_A + N_B}, \qquad 0 \leqslant \Delta N_{AB} \leqslant 1 . \tag{A7}$$

A measure of the difference between ports A and B with respect to the diversion distance (in nautical miles) from the main shipping route:

$$\Delta M_{AB} = \frac{|M_A - M_B|}{M_A + M_B}, \qquad 0 \leqslant \Delta M_{AB} \leqslant 1 . \tag{A8}$$

A measure of the difference between ports A and B in terms of the terminal-operators base:

$$\Delta P_{AB} = 1 - \left[\sum_{k=1}^{p}\frac{(T_{Ak}\,T_{Bk})}{(T_{Ak}\,T_{Bk})+1}(T_{Ak}+T_{Bk})\right]\Big/(T_A + T_B), \qquad 0 \leqslant \Delta P_{AB} \leqslant 1 . \tag{A9}$$

A value of 1 indicates that there are no container-handling companies operational in port A which are also operational in port B. A value of 0 means that all terminal operations in both ports are controlled by one and the same terminal-operator group.

A measure of the difference between ports A and B with respect to the covered storage capacity in the port area:

$$\Delta W_{AB} = \frac{|W_A - W_B|}{W_A + W_B}, \qquad 0 \leqslant \Delta W_{AB} \leqslant 1 . \tag{A10}$$

where

T_A is the container throughput of port A (in TEU),
T_B is the container throughput of port B (in TEU),
$T_{Ai}(T_{Bi})$ is the container throughput of port A (B) in relation to foreland region i (in TEU),
$T_{Aj}(T_{Bj})$ is the container throughput of port A (B) in relation to hinterland region j (in TEU),
$T_{Ak}(T_{Bk})$ is the container throughput of terminal operator k in port A (B) (in TEU),
$C_A(C_B)$ is the planned terminal-capacity increase in container port A (B) for the period 2005–15 (in TEU),
$N_A(N_B)$ is the tide-independent draft (in feet) of container port A (B),
$M_A(M_B)$ is the diversion distance of the main shipping route (in nautical miles) for container port A (B),
$W_A(W_B)$ is the covered storage capacity (in m^2) of port A (B).