SPATIAL (DE)CONCENTRATION OF CONTAINER FLOWS: THE DEVELOPMENT OF LOAD CENTRE PORTS AND INLAND HUBS IN EUROPE

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Abstract

This paper examines the interdependency between (de)concentration processes in port systems and the spatial and functional development of hinterland networks. The prevailed assumption that container flows in the European container transport system are getting more and more concentrated in a few major load centre ports is tested by applying Gini coefficients and 'total shift' analyses. Furthermore it is demonstrated that network (trans)formation and hub formation in the European inland waterway and multimodal rail network clearly affect the level of concentration in the port system and the performance of the European container transport system.

INTRODUCTION

This paper examines recent concentration and deconcentration tendencies and load centre development in the European container port system and network development in the European hinterland. It will be demonstrated that concentration patterns in the European port system are strongly entwined with the development of hinterland networks.

The strong interdependency between a port's foreland and hinterland is very apparent when considering the rise of containerisation and intermodality in Europe and the US. The container and intermodality concept revolutionized modern shipping and, at a later stage, hinterland transportation. The new requirements imposed by containerisation contributed to the decline of some established ports and to the growth of new ones and reshaped port hierarchy. The concept of containerisation extended ports' hinterlands in a way it redefined both port competition and inland transportation.

THE SPATIAL DEVELOPMENT OF PORT SYSTEMS AND HINTERLAND NETWORKS

Only few theoretical models on concentration and deconcentration developments within seaport systems and their hinterland networks exist. The idealized model on network development as presented by Taaffe *et al* (1963) suggests an increasing level of port concentration as certain hinterland routes develop to a greater extent than others in association with the increased importance of particular urban centres. The geographical system evolves from an initial pattern of scattered, poorly connected ports along the coastline to the sixth and final stage of the Taaffe *et al* model, whereby a main network consisting of corridors between gateway ports and inland hubs situated near major urban central places is established. The resulting port concentration can cause degradation of minor ports in the network. Eventually, some smaller ports may even disappear.

The model developed by Barke (1986) is quite similar to the Taaffe *et al* model. In the final stage of his five phased model he introduces, however, a process of deconcentration. This occurs when large and rapidly growing port areas begin to suffer from excessive congestion, thus encouraging some port activities to leave the urban core for less congested suburban or peripheral port sites. In a less extreme form this deconcentration phase refers to the downstream infrastructural extension of ports away from the historical core to less urban port areas. In a more extreme form this deconcentration tendency might imply an activity shift from major ports to adjacent less congested (new) ports.

Hayuth describes a similar spatial deconcentration process, Hayuth (1981). In his model on the dynamics within container port systems five phases are distinguished with different characteristics as regards concentration patterns, port-hinterland relationships and technological innovations. When containerisation becomes a dominant technique in the general cargo trade, the intermodal transport network expands and container traffic concentrates on a limited number of larger ports, the so called 'load centres'. Such a concentration trend is the result of forces in all three segments of the integrated intermodal transportation system: the ocean voyage, the transit through the port and the hinterland transport, Hayuth (1982).

In the fifth and final phase, Hayuth introduces the trend towards deconcentration in the container port system as a result of what he calls 'the peripheral port challenge' (Hayuth, 1981). As the port system develops, diseconomies of scale in some load centres emerge in the form of a lack of space for expansion and limited foreland or hinterland accessibility (port congestion due to infrastructural or superstructural bottle-necks). These constraints to the growth of the load centres encourage smaller ports to attract carriers from these load centres. A certain degree of deconcentration in the container port system takes place when some of the carrier activity is relocated from the larger to the smaller ports. The competitive battle for favourable inland penetration results in complex, partially shared hinterland networks. The concept of 'the peripheral port challenge' was used to give an explanation to deconcentration in the US container port system in the time-span 1970-1985 (Hayuth, 1988).

It is interesting to examine the validity of the presented theoretical models in a European context. Therefore, this paper will consecutively examine (1) the concentration or deconcentration in the European container port system, (2) the network development in the European multimodal rail system and (3) the dynamics in the European inland waterway network.

(DE)CONCENTRATION IN THE EUROPEAN CONTAINER PORT SYSTEM

The methodology used to assess concentration dynamics in the European container port system has previously been applied in Notteboom (1997). In this paper the analysis is extended to traffic data for the period 1975-1996 for 43 situated in four European port ranges: the Hamburg-Le Havre range (11 ports), the Atlantic range (9 ports), the European Mediterranean range (18 ports) and the UK range (5 ports on the east and south coast), see Table 1.

Table 1 - Overview of ports condidered in this study

Hamburg-Le Havre range	Atlantic range	Mediterranean range	UK range
Bremerhaven (D)	St-Nazaire (F)	Algeciras (E)	Hull (GB)
Hamburg (D)	Bordeaux (F)	Valencia (E)	Felixstowe (GB)
Rotterdam (NL)	Pasajes (E)	Tarragona (E)	Thamesport (GB)
Flushing (NL)	Bilbao (E)	Barcelona (E)	Tilbury (GB)
Amsterdam (NL)	Vigo (E)	Sète (F)	Southampton (GB)
Zeebrugge (B)	Leixos (P)	Marseille (F)	
Antwerp (B)	Lisbon (P)	Savona (I)	
Ghent (B)	Cadiz (E)	Genoa (I)	
Dunkirk (F)	Sevilla (E)	La Spezia (I)	
Rouen (F)		Leghorn (I)	
Le Havre (F)		Naples (I)	
		Gioia Tauro (I)	
		Marsaxlokk	
		Ravenna (I)	
		Venice (I)	
		Trieste (I)	
		Thessaloniki (GR)	
		Piraeus (GR)	

The general positioning of the container port ranges in Europe

The proposed classification of the European container port system into four main port ranges is particularly interesting in view of the assessment of inter-range port competition, i.e. the competition between ports situated in different port ranges. It is suggested that extensive hinterland networks allowed deeper inland penetration and contributed to the establishment of vast hinterlands shared by the major European ports. These developments encouraged inter-range port competition, Winkelmans and Notteboom (1994).

Figure 1 represents the traffic evolution, expressed in TEU, for the four port ranges in the period 1975-1996. Although container traffic in the Mediterranean range grows rapidly, the majority is still handled by the seaports of the Hamburg-Le Havre range (14.1 million TEU in 1996). Table 2 illustrates the dominance of the Hamburg-Le Havre. The four largest container ports of the Hamburg-Le Havre range (i.e. Rotterdam, Antwerp, Hamburg and Bremen) together handled half of the total container throughput in the European port system in 1975, 48 per cent in 1985 and 44 per cent in 1996.

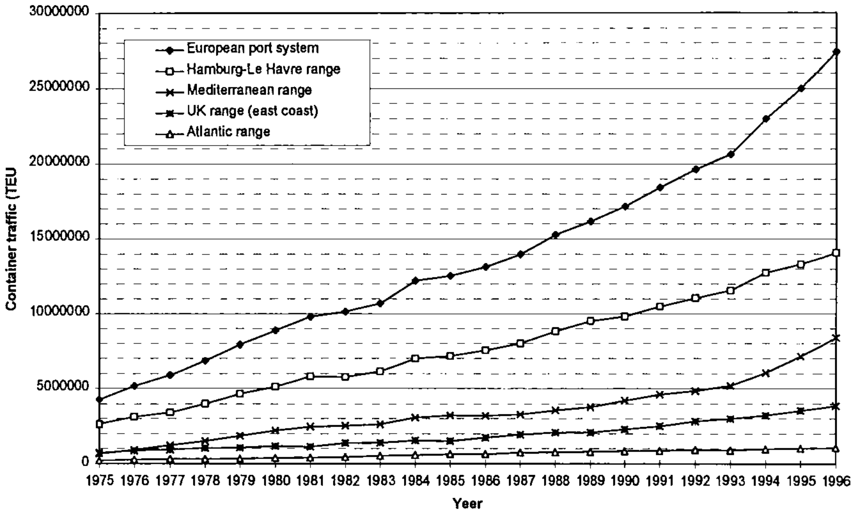

Figure 1 - Container traffic for given port ranges, 1975-1996 (in TEU)

Table 2 - Top-ten European container ports in 1975, 1985 and 1996

1975			1985			1996		
Port	**'000 TEU**	**%**	**Port**	**'000 TEU**	**%**	**Port**	**'000 TEU**	**%**
Rotterdam*	1 079	25.2%	R'dam*	2 655	21.2%	Rotterdam*	4 936	18.0%
Bremen*	410	9.6%	Antwerp*	1 243	9.9%	Hamburg*	3 054	11.1%
Hamburg*	326	7.6%	Hamburg*	1 159	9.2%	Antwerp*	2 654	9.7%
Antwerp*	297	7.0%	Bremen*	986	7.9%	Felixstowe	2 065	7.5%
Tilbury	232	5.4%	Felixstowe	726	5.8%	Bremen*	1 543	5.6%
Le Havre*	231	5.4%	Le Havre*	566	4.5%	Algeciras	1 307	4.8%
Felixstowe	230	5.4%	Marseille	488	3.9%	Le Havre*	1 020	3.7%
Southampton	199	4.7%	Leghorn	475	3.8%	La Spezia	971	3.5%
Zeebrugge*	184	4.3%	Tilbury	387	3.1%	Genoa	826	3.0%
Genoa	162	3.8%	Barcelona	353	2.8%	Southampton	808	3.0%
Top-ten	3 351	78.4%		9 037	72.1%		19 184	70.0%
Port System (43 ports)	4 273	100%		12 539	100%		27 395	100%

Note: * = port of the Hamburg-Le Havre range

Some of the European load centre ports (e.g. Rotterdam, Genoa and Antwerp) existed long before the container revolution, have invested early in the technologies, thus supporting the premise of 'the importance of being first' and later on received load centre status. Other, formerly non-existing or very small ports, gained eminent status as load centre as a result of heavy financial port investments, assuring higher technical productivities, in combination with a favourable geographic location (e.g. Zeebrugge, Algeciras, Marsaxlokk and Gioia Tauro).

The decrease of the market share of the ten largest ports in the total European container traffic gives a first, though general, indication that the container handling business in Europe is becoming less concentrated. A more profound analysis of the level of concentration is provided in the next section.

Gini coefficients for the European container port system

In this section, the prevailing assumption that the European port system is concentrated in fewer and larger ports is tested, based upon calculation of Gini coefficients. The Gini coefficient is a widely used index that measures per cent departure from a perfectly uniform distribution. If all the ports in a port system are equal of size, the Gini coefficient will equal zero. In case one port accounts for the total volume of containers (full concentration), the Gini coefficient equals unity. Gini coefficients have previously been applied in Kuby and Reid (1992), Hayuth (1988) and Notteboom (1997).

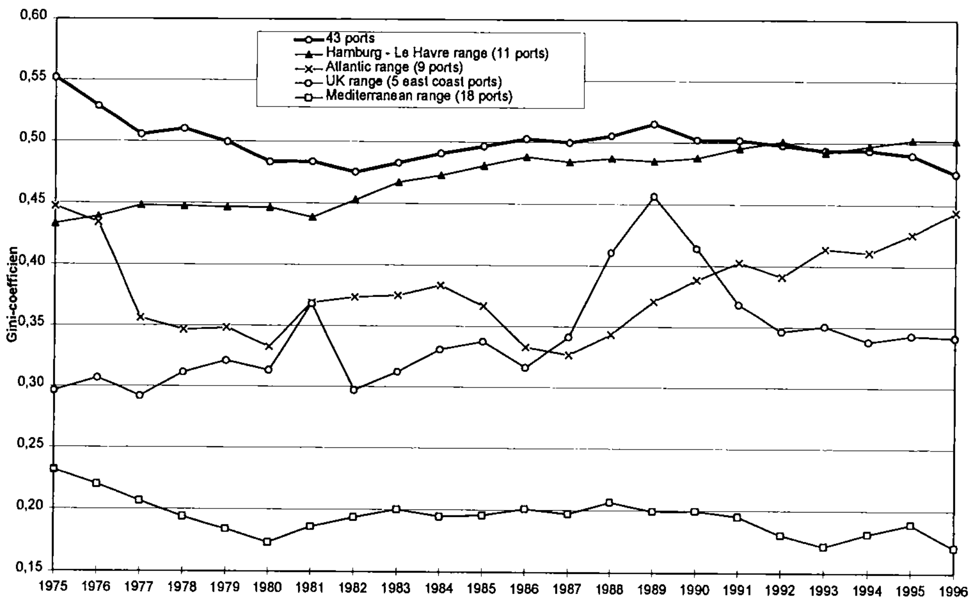

Figure 2 - Gini coefficients for the European container port system

Figure 2 represents the results for the European container port system as well as for the different port ranges. Three phases can be distinguished for the total port system. The value of the Gini coefficient for all ports initially decreased from 0.55 in 1975 to 0.47 in 1982, indicating a modest trend towards a more evenly distributed system. In the second phase between 1982 and 1989, the European port system witnessed a slight concentration tendency. The third phase started in 1989 and involves a clear deconcentration.

At range level, figure 2 reveals that the Hamburg-Le Havre range records a slight concentration tendency. Noteworthy is that the growing level of concentration is not the result of the increasing supremacy of Rotterdam. The market share of Rotterdam in the total European continental container port system dropped from 25.2 per cent in 1975 to 18 per cent in 1996, see table 2. As such, the megaport idea is not confirmed. The very low Gini coefficient in the Mediterranean range indicates that the container flows in the Mediterranean are fairly evenly distributed over the different ports. A moderate deconcentration tendency could be observed in the 1990s, which primarily results from the hub battle among the existing and new medium-sized load centres. The UK range witnessed a sharp concentration tendency during the late 1980s as a result of the traffic boom in Felixstowe. From 1990 on also other UK ports, such as Southampton and Thamesport, were able to benefit from the rise in the UK container business, leading to a more evenly distributed port range.

Applying the 'total shift' analysis to the European container port system

The 'total shift' analysis examines the volume of container shifts among ports, port ranges and port categories (small and medium-sized as well as large ports). As such, the analysis provides a more detailed insight in the concentration dynamics. The total shift reflects the total number of containers (c.q. TEU) an individual port, a port range or a port category has actually lost to or won from competing units. Additional relevant information can be obtained by calculating the net volume of containers shifted between individual ports, port ranges or port categories. Periods characterised by high net volume shifts refer to a considerable degree of dynamics and competition within the container port system. For a mathematical representation of the 'total shift' analysis see Notteboom (1997). The total shift analysis in this paper is applied to five periods, see table 3.

Tabel 3 - The European port system during the five periods considered

	Port system growth '000 TEU	Average annual growth '000 TEU	Average annual %-growth	Concentration pattern in the European port system (see also figure 2)
1975-1982	5 840	834	13.10%	strong deconcentration
1982-1987	3 848	770	6.66%	moderate concentration
1987-1991	4 484	1 121	7.21%	till 1989 moderate concentration, afterwards deconcentration
1991-1994	4 526	1 509	7.59%	weak deconcentration
1994-1996	4 424	2 212	9.21%	strong deconcentration

Table 4 presents the results of a **range-based 'total shift' analysis** applied to the European container port system. $VOLSHFT_{total}$ is the average annual total net volume of TEU shifted between container ports in the system. $VOLSHFT_{inter}$ indicates the average annual net volume of TEU shifted between ports situated in different ranges. The higher this figure the higher inter-range competition in the port system. Finally, $VOLSHFT_{intra}$ represents the average annual net volume of TEU shifted between ports situated in the same range. The sum of the total inter-range net volume shifts and the total intra-range net volume shifts equals $VOLSHFT_{total}$. The average annual total shift figures for the port ranges and the individual ports indicate a gain (positive sign) or a loss (negative sign) of 'potential' container traffic i.e. compared to the situation under which the considered port range or individual port would have grown at the same average growth rate as the total port system.

Table 4 - A range-based 'total shift' analysis, average annual shifts in TEUs

	1975-1982	1982-1987	1987-1991	1991-1994	1994-1996
$VOLSHFT_{total}$	229 447 TEU	229 760 TEU	310 532 TEU	390 898 TEU	764 042 TEU
per cent of traffic in t_0	(5.4 %)	(2.3 %)	(2.2 %)	(2.1 %)	(3.3 %)
$VOLSHFT_{inter}$	137 415 TEU	43 088 TEU	65 584 TEU	131 742 TEU	611 445 TEU
$VOLSHFT_{intra}$	92 031 TEU	186 672 TEU	244 948 TEU	259 156 TEU	152 598 TEU
Of which:					
- Hamburg-Le Havre	52 898 TEU	91 623 TEU	75 958 TEU	88 171 TEU	18 486 TEU
- Atlantic range	5 220 TEU	8 711 TEU	5 250 TEU	19 435 TEU	3 629 TEU
- Mediterranean range	21 982 TEU	56 872 TEU	119 136 TEU	120 024 TEU	69 248 TEU
- UK range	11 931 TEU	29 466 TEU	44 603 TEU	31 525 TEU	61 235 TEU
Average annual total shifts between ranges:					
- Hamburg-Le Havre	- 73 313	+ 6 979	- 21 348	- 96 432	- 559 599
% of traffic in t_0	(- 2.8 %)	(+ 0.1 %)	(- 0.3 %)	(- 0.9 %)	(- 4.4 %)
- Atlantic range	- 10 349	+ 25 357	- 32 768	- 35 310	- 51 846
% of traffic in t_0	(- 4.7 %)	(+ 5.6 %)	(- 4.4 %)	(- 4.1 %)	(- 5.4 %)
- Mediterranean range	+137 415	- 43 088	+ 65 584	+ 104 588	+ 596 652
% of traffic in t_0	(+ 20.7 %)	(- 1.7 %)	(+ 2.0 %)	(+ 2.3 %)	(+ 9.9 %)
- UK range	- 53 753	+ 10 752	- 11 468	+ 27 154	+ 14 793
% of traffic in t_0	(- 7.3 %)	(+ 0.8 %)	(- 0.6 %)	(+ 1.1 %)	(+ 0.5 %)
Major winners in terms of average annual total shift ('000 TEU)	Ravenna: +27 Algeciras: +24 Marseille: +21 La Spezia: +21 Antwerp: +20 Leghorn: +18 Hamburg: 17 Rouen: +15 Felixstowe: +12 Naples: +11	Antwerp: +54 Hamburg: +45 Felixstowe: +37 Barcelona: +18 Leghorn: +17 Valencia: +12 Lisbon: +11 Vigo: +8 Algeciras: +7 Leixos: +4	Hamburg: +68 La Spezia: +50 Algeciras: +49 Marsaxlokk: +39 Thamesport: +34 Piraeus: +28 Thessaloniki: +15 Felixstowe: +11 Rotterdam: +4 Le Havre: +3	La Spezia: +82 Zeebrugge: +77 Marsaxlokk: +62 Genoa: +28 Thamesport: +24 Thessaloniki: +22 Southamp.: +22 Algeciras: +18 Hull: +12 Bilbao: +9	Gioia Tauro:+286 Genoa: +107 Valencia: +76 Marsaxlokk: +68 Algeciras: +55 Southamp.: +48 Thamesport: +28 Barcelona: +23 Thessaloniki: +16 Venice: +15
Major losers in terms of average annual total shift ('000 TEU)	Rotterdam: -56 Zeebrugge: -37 Tilbury: -32 Southamp.: -28 Bremen: -25 Genoa: -22 Hull: -6 Bilbao: -6 Duinkerken: -3 Leixos: -3	Rotterdam: -29 Marseille: -25 Ravenna: -21 Tilbury: -19 Rouen: -17 La Spezia: -12 Bremen: -11 Southamp.: -11 Le Havre: -11 Naples: -10	Leghorn: -55 Tilbury: -35 Antwerp: -34 Bremen: -25 Hull: -21 Marseilles: -16 Valencia: -15 Ravenna: -14 Cadiz: -13 Rouen: -12	Le Havre: -90 Rotterdam: -50 Leghorn: -47 Marseilles: -40 Bremen: -29 Lisbon: -28 Piraeus: -20 Felixstowe: -17 Tilbury: -14 Pasajes: -12	Rotterdam: -239 Bremen: -125 Hamburg: -98 Zeebrugge: -87 Hull: -38 Cadiz: -26 Tilbury: -22 Piraeus: -20 Savona: -16 Leghorn: -13

The average annual total net volume of shift effects within the European container port system increased from 229 447 TEU in the first period to 390 898 TEU in the period 1991-1994. In the last period this figure boomed to 764 042 TEU, representing some 3.3 per cent of total container throughput in the European container port system in 1994. The share of inter-range shifts in the total net volume shift amounts to around 60 per cent in the first period, between 20 and 35 per cent in the next three observation periods and 80 per cent in the last. As such, the net volume of containers shifted between the respective ranges reached an exceptionally high level in the last period, pointing to very high inter-range competition in Europe. In that time-span the Hamburg-Le Havre range missed a potential growth of approximately 560 000 TEU per annum (some 4.4 per cent of total range traffic in 1994) primarily to ports situated in the Mediterranean and to a lesser extent to UK ports. In general, the Mediterranean range marks elevated average annual shift figures, except for the decline in the second period. The Hamburg-Le Havre range and the Atlantic range are the worst performers, albeit with losses for northern ports being limited in terms of traffic shares.

Among the major winners and losers in terms of total shifts we find a large number of Mediterranean ports with, on the one hand, La Spezia, Marsaxlokk, Algeciras and in recent years Gioia Tauro and Genoa showing the best overall performances and, on the other hand, Leghorn and Marseilles showing the worst. In the Hamburg-Le Havre port range, Antwerp and Hamburg represent the major winners till the early 1990s, whereas Bremen, Le Havre and especially Rotterdam lost most potential container traffic during the observation period. Compared to the total container traffic of Rotterdam, the losses for this port are, however, quite moderate (i.e. ranging from 5.1 per cent in the period 1975-1982 to 5.2 per cent in the last period of observation). In the UK range, Southampton and Thamesport outperform the other UK ports in the last two periods.

Table 5 - A category-based 'total shift' analysis, average annual shifts in TEUs

	1975-1982	1982-1987	1987-1991	1991-1994	1994-1996
$VOLSHFT_{total}$ per cent of traffic in t_0	229 447 TEU (5.4 %)	229 760 TEU (2.3 %)	310 532TEU (2.2 %)	390 898 TEU (2.1 %)	764 042 TEU (3.3 %)
$VOLSHFT_{inter}$	24 967 TEU	92 466 TEU	74 151 TEU	164 333 TEU	449 555 TEU
$VOLSHFT_{intra}$	204 480 TEU	137 294 TEU	236 380 TEU	226 585 TEU	314 487 TEU
Of which:					
- Small ports (<100.000 TEU)	10 265 TEU	20 438 TEU	21 121 TEU	36 883 TEU	43 001 TEU
- Medium-sized ports (100 000-400 000 TEU)	121 303 TEU	66 732 TEU	155 810 TEU	166 592 TEU	206 259 TEU
- Large ports (> 400 000 TEU)	72 912 TEU	50 124 TEU	59 449 TEU	23 091 TEU	65 227 TEU
Average annual total shifts between categories:					
- Small ports (<100.000 TEU)	+ 24 967	- 37 424	- 59 346	+ 8 122	- 40 952
% of traffic in t_0	(+ 12.1 %)	(- 5.6 %)	(- 8.2 %)	(+ 1.1%)	(- 4.4 %)
- Medium-sized ports (100 000-400 000 TEU)	- 15 039	- 55 041	- 14 805	+ 156 211	+ 449 555
% of traffic in t_0	(- 1.0 %)	(- 1.7 %)	(- 0.3 %)	(+ 2.8 %)	(+ 6.0 %)
- Large ports (> 400 000 TEU)	- 9 928	+ 92 466	+ 74 151	- 164 333	- 408 603
% of traffic in t_0	(- 0.4 %)	(+ 1.5 %)	(+ 0.8 %)	(- 1.4 %)	(- 2.8 %)
Winners in terms of average annual total shift ('000 TEU) (a)	M (M): +99 M (L): +24 M (S): +14 UK (L): +12 H-LH (S): +9 A (S): +1	H-LH (L): +48 UK (L):+37 A (S): +14 A (M): +12 A (L): +7	M (L): +49 H-LH (L): +15 UK (L): +11 M (S): +9 M (M): +8 H-LH (M): +2	H-LH (M): +77 M (M): +58 UK (M): +44 M (S): +28 M (L): +18	M (M): +541 M (L): +55 UK (M): +16 M (S): +1
Losers in terms of average annual total shift ('000 TEU) (a)	UK (M): -66 H-LH (L): -46 H-LH(M): -37 A (M): -12	H-LH (S): -38 M (M): -37 UK (M): -26 M (S): -13 H-LH (M): -4	H-LH (S): -38 A (S): -31 UK (M): -22 A (M): -2	H-LH (L): -165 A (M): -23 UK (L): -17 A (S): -12 H-LH (S): -8	H-LH(L): -462 H-LH(M): -87 A (S): -30 A (M): -21 H-LH (S): -11 UK (L): -2

(a) H-LH = Hamburg - Le Havre range, A = Atlantic range, M = Mediterranean range, UK = UK range (east coast)
(L) = large ports, (M) = medium-sized ports, (S) = small ports.

In a similar way to the assessment of shifts on a range level, shifts between port categories can be calculated. After preliminary testing, it was decided to make a distinction between small ports (average container traffic for the period 1975-1996 of less than 100 000 TEU), medium-sized ports (between 100 000 and 400 000 TEU) and large container ports (at least 400 000 TEU). Under these assumptions, the European container port system considered in this paper consists of 16 small, 20 medium-sized and 7 large container ports. The results of the **category-based 'total shift' analysis** are presented in Table 5.

The shifts between the medium-sized ports exceed other intra-category shifts, indicating that their exists a fierce competition within this container port segment. Container shifts between the different port categories have risen considerably over time to reach 449 555 TEU in the period 1994-1996. The average annual total shift figures confirm the findings related to figure 2. Up to the early 1980s, the faster growth of smaller ports and the engagement of new ports into the container business caused deconcentration in the European seaport system. During the 1980s, concentration within the port system took place, as the small and medium-sized ports lost ground to the larger ports. However, the two final periods of observation are introducing a slight deconcentration, for the medium-sized container ports managed to attract large volumes from the larger ports. In general, the position of the large ports in the Hamburg-Le Havre range deteriorated the most; from a positive average annual total shift of 48 000 TEU in the second period to a negative shift effect of 462 000 TEU in the last. Major winners include the English and Mediterranean medium-sized ports.

An empirical verification of the theoretical models

It is useful to fit the results of the concentration and 'total shift' analyses into the development patterns of port systems as described by the models of Taaffe *et al*, Barke and Hayuth. At first sight, the deconcentration pattern observed during the 1990s for the European system points to a 'peripheral port challenge' phase. A range-based evaluation supplemented with qualitative elements, however, offers more insight on that particular topic.

Most deepsea RTW services on the trades Europe-Far East and Europe-North America used to call at northern ports only. Recently major container shipping lines commenced to include Mediterranean ports directly in their RTW services. This ultimately led to additional loops focussed on the trade between the Mediterranean and non-European regions. In reply to these changes in the strategy of the container shipping sector, new Mediterranean ports have emerged to accommodate RTW services with the best technology and location. Location factors (closeness to main RTW route) seem to be the primary reason for the emergence of new ports and not congestion or the lack of space in the existing ports. The hub battle partly shifted activities from remote ports, in terms of the diversion distance from the main RTW-route (i.e. maritime track linking the Suez-canal to the Straits of Gibraltar), to nearby ports such as Algeciras, Marsaxlokk and Gioia Tauro.

Figure 2 illustrated that the concentration trend in the Hamburg-Le Havre range stagnated in the 1990s. In comparison to the Mediterranean port range, ports in the Hamburg-Le Havre range nowadays are more confronted with possible diseconomies of scale connected to large-scale containerisation. However, these diseconomies of scale did not lead to radical deconcentration in the port system as described in the Hayuth model but merely to a deconcentration tendency limited in space. Hence, ports have extented activities to nearby new port areas. For instance, Rotterdam developed massive container terminals on the 'Maasvlakte' and is planning to build a second 'Maasvlakte'. Its inland position forces the port of Antwerp to look for port extension by turning land to docks. The new plans of Antwerp include a container tidal dock on the left bank of the river Scheldt. Apart from Zeebrugge, it seems that for the near future no new port in the Hamburg-Le Havre range will present itself as an alternative to the five large container ports (Rotterdam, Hamburg, Antwerp, Bremen, Le Havre), notwithstanding the fact that these ports are increasingly confronted with bottle-necks in maritime and land accessibility. The land side and in particular hinterland corridor and network development will undoubtedly proof to be crucial for the Hamburg-Le Havre port range in view of keeping the competitive edge over the Mediterranean range.

THE DEVELOPMENT OF HINTERLAND NETWORKS AND INLAND HUBS

The theoretical models on port system development as described above remain vague for what the impact of hinterland network development on the concentration pattern in a port system is concerned. This section links the functional and spatial characteristics of the rail and inland waterway networks in Europe to the results obtained from the concentration analysis for the European port system.

Networking in the multimodal rail system

The changes in the port hierarchy and the growth of containerised flows on a international scale put an immense pressure on the collection and distribution networks around seaports. Inland load centres enable to extend the transportation network inland far beyond the seaports, thus relieving some pressure of the collection and distribution networks. In the relation between the maritime and inland hubs seaborne transport, rail and inland navigation become attractive. The concentration of traffic flows on high volume multimodal trunk routes or corridors between seaports and large inland hubs is the most apparent result of this spatial and functional development. In this respect, inland hub and corridor formation is indispensable for allowing large-scale concentration in a port system.

The phenomena discussed above can be placed in a formal theoretical model on the spatial development of an inland network. Figure 3 describes such a theoretical model for the rail sector. In the first phase the economies of scale in the large container ports enables them to extend their hinterland. The market area of the smaller ports, however, is limited to inland centres in the immediate hinterland. In the second phase, self-reinforcing effects intensify the hinterland penetration level of the load centres and consequently enhance the concentration tendency in the port system. Lines of major penetration emanate from the load centres and it are these ports that can now possibly capture the hinterlands of neighbouring smaller ports. The latter ports find themselves confronted with a vicious circle. The small-scale container transhipment activities do not allow to install frequent block and shuttle trains to the more distant hinterlands. Because of the inability to serve a substantial hinterland, the major shipping lines do not include the smaller ports in their RTW-services. This results in even lower volumes destined for the distant hinterland. Therefore, smaller ports tend to channel some of their container traffic to the larger ports in order to benefit from their extensive hinterland network. The hub-feeder hierarchy further strengthens the competitive position of the load centre port. However, the large load centre is still not able to compete effectively with smaller ports that are situated closer to a specific distant hinterland (e.g. the seaport on the right hand side of figure 3). Hence, the shuttle and block trains departing from the load centre port and destined for these distant hinterlands have a low frequency and high lead time because of limited container volumes. This impedes a further massive inland expansion of the rail network emanating from the load centre port.

In the third phase, inland hub formation in the distant hinterlands takes place. The spatial structure evolves from a poorly connected system of inland terminals of equal status to a hub-and-spoke network. The load centre port still serves as a hub for the more immediate hinterland. The concentration of long distance rail traffic on few high volume trunk lines offers the mainport some opportunities to effectively compete with more distant container ports. New inland terminals emerge along the corridors. Initially, these terminals benefit on a limited scale from the cargo flows passing through the corridors.

In the fourth phase, some of the new inland terminals in the more immediate hinterland of the load centre port develop into major inland rail hubs. The mainport becomes a mini-hub in the rail network. The new inland hub serves as a master-hub. The neighbouring smaller ports are now able to use the extensive hinterland network without relying on the load centre port. The use of the master hub by small and large ports of the same port cluster strengthens the trend towards a certain degree of deconcentration in the port system. The multimodal rail network becomes fully integrated when all inland master-hubs are interconnected via high-frequency block trains. The increasing number of inland centres in the rail network has large consequences on the complexity and structure of the collection and distribution network.

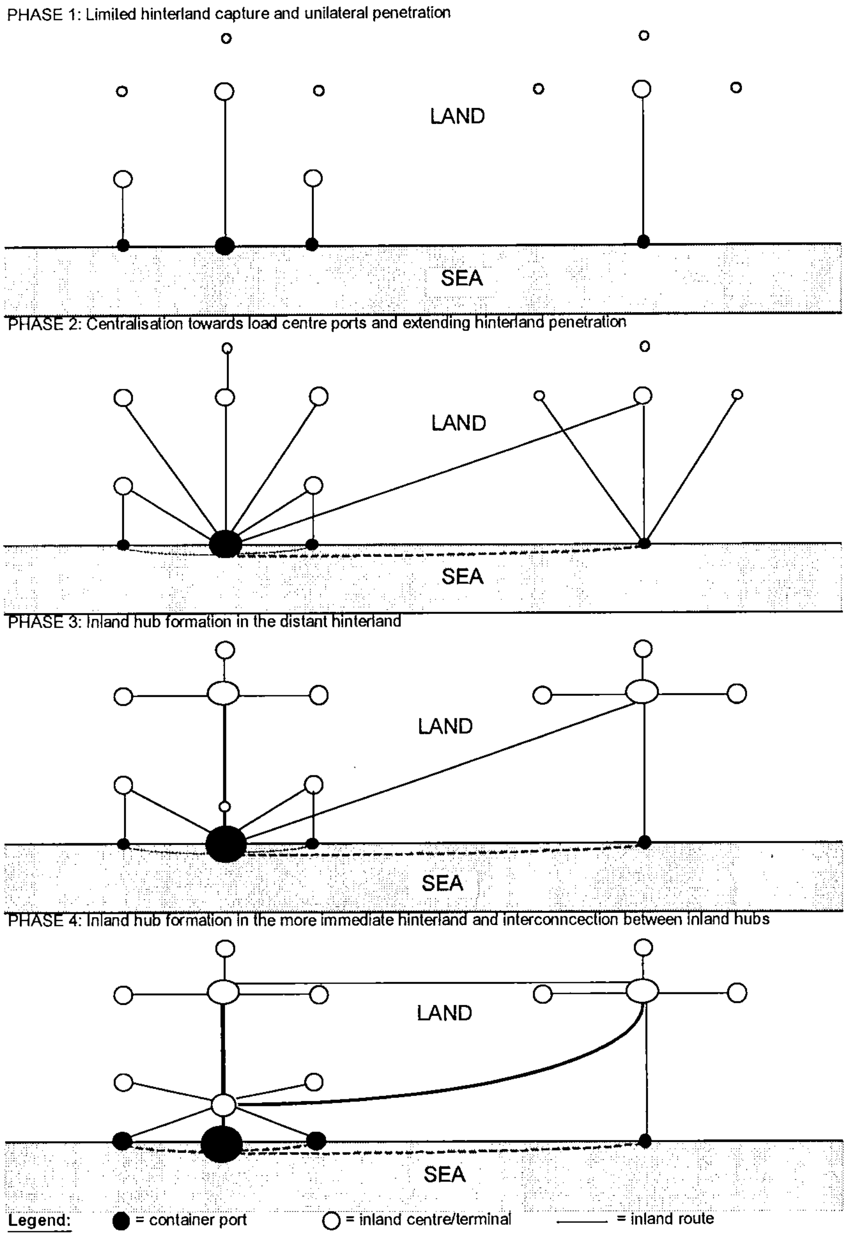

Figure 3 - A theoretical model on the development of a port-linked intermodal rail network

The proposed theoretical model can be illustrated by looking at the rail network development of the Rhine-Scheldt delta container ports towards southern Europe. In recent years numerous multimodal railway networks have emerged similar to those in phases three and four of the model. Qualitynet of Intercontainer-Interfrigo (ICF), the most important European intermodal actor in rail traffic, uses Metz-Sablon in the north-east of France as master hub linking up the Rhine-Scheldt delta ports with the rest of Europe. Shuttle trains from the mainports carrying containers for many destinations arrive in Metz-Sablon on a regular basis to form block trains destined for specific locations in the distant hinterland of the Rhine-Scheldt delta ports. The North European Network (NEN), jointly operated by the French company CNC (Compagnie Nouvelle de Conteneurs), Inter Ferry-Boats (a subsidiary of the Belgian railway company NMBS) and Terminal Athus, is based on the same principle, but covers a smaller geographical area. The Dry Port of Muizen, between Antwerp and Brussels, serves as a master-hub within NEN.

These kind of hub-and-spoke networks enlarge the possibilities and competitiveness of rail shuttles. From a seaport perspective it is much easier to fill a mixed block train containing cargo for various destinations to a nearby inland hub than to run a direct dedicated block train to a final destination in the distant hinterland. Moreover, the services offered by the master-hubs allow to increase the frequency of the scheduled services between the load centres and the distant destinations.

It can be concluded that the intermodal rail network in Europe developed well in recent years. The network is slowly evolving from phase 3 to phase 4 of the proposed model, albeit that the interconnection between the different inland hubs has not yet been completed. However, some major obstacles to a highly efficient and free rail market still remain. For instance, the above networks all are operated by subsidiaries or joint-ventures between national railway companies. Due to the slow deregulation process, the railway sector in continental Europe is still dominated by the various national railway companies. In their strategy to offer door-to-door services to the customer, some large container shipping lines aim at increasing their direct involvement in the organization of the hinterland rail transportation. For instance, European Rail Shuttle (ERS), a joint-venture between P&O Nedlloyd, Sea-Land, Maersk and the Dutch national railway company NS, operates shuttle trains between Rotterdam and the inland terminals of Neuss and Germersheim in Germany and Melzo and Padova in Italy. The elevated traction cost remains the main problem associated with the use of services offered by existing railway companies. Another major obstacle to the introduction of block train services are the long preparations and negotiations with the national railway companies needed to install fast direct rail services. The lack of technical standards (e.g. varying current on national electrified networks) and possibilities (e.g. very limited opportunities for double stack trains due to height limits), together with the existing inefficiencies in the organizational structures (e.g. the involvement of several railway companies) undoubtedly have always impeded more elevated rail container flows between north and south Europe. For the future, a fargoing technical harmonization and liberalization in intermodal transportation is needed to enhance the further development of efficient rail corridors and to stimulate the integration of the European port system with its hinterland rail networks.

Container transport within the European inland waterway network

The European inland waterway network covers a fairly small, though economic important part of Europe. The Rhine basin with its tributary rivers is by far the most important inland waterway in Europe. In 1997, total European container traffic by inland barge amounted to some 2.2 million TEU. This number rises each year by a double-digit growth figure. The seaport of Antwerp handled a total barge traffic of approximately 1 million TEU compared to 128 700 TEU in 1985. The river-linked container business in Rotterdam reached an estimated 1.4 million TEU in 1997 versus 225 000 TEU in 1985. An impressive 560 000 TEU were shipped by inland barge between Antwerp and Rotterdam in 1996. The bulk of the remaining container flows is oriented towards the river ports in the Rhine basin. Total Rhine container traffic is estimated at some 0.8 million TEU in 1996.

Barge shuttles link the mainports with the navigation areas on the Rhine and the Danube on a multiporting basis: an inland vessel loads containers at different maritime terminals in a Benelux seaport and then sails to a specific navigation area (e.g. lower Rhine) to load and discharge its cargo at various inland terminals before returning non-stop to the seaport. The scheduled services from the Benelux seaports to navigation areas outside the Rhine basin are not organised on a multiporting basis, i.e. both Antwerp and Rotterdam have direct river services to almost each non-Rhenish terminal separately. To avoid unduly increasing competition among the barge operators and so as to provide customers with best possible service, the operators tend to cooperate in services offered to the various areas in the Rhine basin. For instance, the lower Rhine area is served by the Fahrgemeinschaft Niederrhein, a cooperation between Combined Container Service, Rhinecontainer, Häger & Schmidt and Haniel.

None of the container terminals along the Rhine serves as inland hub for other river ports. Consequently, possible concentration of container traffic in some Rhine basin ports does not result from river-linked hub-and-spoke formation. For instance, Duisburg (96 990 TEU of river transhipment in 1997) and Basel (64 027 TEU) are inland hubs in the barge business not because of their traffic relations with other Rhine terminals but primarily because of : (1) a high demand for container transhipment in their immediate hinterland and (2) their role as intermodal transfer point in flows originating from the load centre ports and destined for more distant hinterland locations situated in land-locked regions that have no or limited inland waterway facilities in the vicinity.

In recent years some major structural changes reshaped the inland terminal network:

- After a period of decentralisation in the Rhine basin, the large barge operators have started to centralise the river-linked container flows in only few terminals. For instance, Combined Container Service (CCS) closed down their terminal in Ginsheim in the beginning of the nineties and abandoned the idea of developing a new terminal in Duisburg or Düsseldorf. Instead, operations are now centralised in Emmerich for the lower Rhine and Ludwigshafen and Koblenz for the middle Rhine;
- The number of barge terminals in the Rhine basin, however, is still increasing as new operators try to enter the market (for example a third terminal in Duisburg which will be operated by ECT). The growing awareness for the potential of inland navigation, in recent years, also lead to the emergence of new intermodal river ports outside the Rhine basin. A lot of these new barge terminals are located close to the load centre ports. This evolution proves that container transport by barge can be both cost effective and competitive on relatively short distances, given sufficient container volumes between the transhipment points;
- A substantial number of container barge operators have extended their logistic services to the customers by offering door-to-door transport. The inland terminals function as key nodes in their logistic strategy. For instance, Rhenania Intermodal Transport operates a logistic network built around its five container terminals along the Rhine. As such, a large number of the European river container terminals have become real logistic centres with tri-modal facilities;
- Barge terminals are increasingly valorizing the complementarity between inland navigation and rail. For instance, a portion of the container flows between the Rhine-Scheldt delta ports and eastern Europe arrives in Duisburg by inland barge for transhipment to rail shuttles towards the final destinations in the Czech Republic, Poland or Slovakia. A further intensification and optimization of the rail-barge transfer function of inland container terminals can exert a major impact on the competitive position of load centre ports in the European port system, especially for what the land-locked locations in large parts of south-east and central Europe (e.g. Romania, Slovakia, the Czech Republic and Hungary) are concerned.

CONCLUSIONS

In general, the economies of scale linked to containerisation are believed to enhance the concentration of large volumes of containers in few load centre ports. Although the load centre concept has merit from the shipping line viewpoint, the prevailed assumption that containerisation would lead to further port concentration is not a confirmed fact. Both the concentration and 'total shift' analyses illustrate that the level of port concentration in the European container port system decreased substantially in recent years. The (new) medium-sized and large load centres in the Mediterranean clearly threat the competitive position of the major ports of the Hamburg-Le Havre range, for the quality improvements and major investments in these load centres and their immediate hinterland infrastructure have already contributed to a partial rechannelization of traditional north-south land and water feeder trades. Especially for the geographical market segments of northern Italy, Switzerland, southern Germany, Spain, the middle and south of France and some east European states, inter-range port competition between northern and Mediterranean ports will undoubtedly increase in the coming years.

On an individual port range level it could be concluded that the 'peripheral port challenge' concept of the Hayuth model does not apply in Europe. Zeebrugge, the only medium-sized port that presented itself as an alternative for the large container ports in this range, could not prevent a further concentration in the northern range. In the Mediterranean, the slight deconcentration tendency was a result of container shifts to medium-sized (new) ports, which offer a more favourable location in view of receiving RTW services.

The future development of the European container port system will primarily be influenced by the technological and organizational evolutions in the triptych foreland-port-hinterland and the outcomes of some current (trans)port policy issues. The further diffusion of container technology and the ambition of many container operators to offer door-to-door services could involve a disinterest regarding which ports are used, causing deconcentration. But the technological and economic requirements exerted by the container shipping sector (e.g. the push for more sophisticated services) could lead to more concentration.

It was demonstrated that the master and mini-hub configuration employed in the organization of scheduled rail services to distant hinterlands differs a lot from the hopper system used in the Rhine area of the inland waterway network. However, if we take a look at the spatial and functional relations between the load centre ports in northern Europe and the inland terminals in both the inland waterway network and the multimodal rail network a lot of similarities seem to exist. The emergence of master rail hubs and barge terminals in the immediate hinterland of the load centres implies a transfer of a part of the collection and distribution function inland away from these ports. The corridors between seaports and inland centres enable to extend the high volume transportation network across the borders of the port area. These inland terminals acquire an important satellite function with respect to the seaports, as they help to relieve the seaport areas of potential congestion. However the danger exists of simply moving bottlenecks from the load centre ports to the inland centres of the hinterland network.

Van Klink (1995) argues most European mainports nowadays no longer can operate on a city-port level but should actively enhance the development of port networks by engaging into strategic alliances with other nodes (other ports and inland terminals) in the relevant transport networks. The recent initiatives in this field taken by northern ports like Antwerp and Rotterdam on the one hand and terminal operators like ECT of Rotterdam on the other, illustrate that participation in hinterland networks is considered as a crucial element in view of port competition on the different geographical levels (intra-range and inter-range).

The impact of inland terminal network development on the concentration pattern in seaport systems remains uncertain. On the one hand the inland terminal development in the rail business and the inland waterway sector prevents a further overcrowding of the limited port areas in major load centres. Under these circumstances, it is easier for load centre ports to preserve their attractiveness and to fully exploit their potential economies of scale. The corridors towards the inland terminal network create a margin for further growth of the seaborne container traffic in the load centre ports and thus might enhance a further concentration in the port system. However, insofar smaller adjacent ports succeed in benefiting from the opportunities offered by the extensive hinterland networks, a certain degree of deconcentration in the port system might appear.

The outcome of these contradicting tendencies will primarily be determined by (1) the effectiveness by which the respective port authorities and port companies succeed in developing strong functional ties with the nodes in the hinterland network, (2) the effectiveness by which seaports try to attract and retain some of the 'footloose' megacarriers in the container shipping sector that are active in the organization of door-to-door transport chains and (3) the effectiveness by which the load centres are able to benefit from public-private interdependencies on a regional, national and supranational level for what the decision making on and financing of infrastructural port projects and (cross-border) hinterland networks is concerned. The latter includes the issue of subsidisation of seaport terminal development, multimodal services and inland terminal operations and the issue of the application of 'the user pays' principle in port and hinterland services. The above elements also determine the outcome of inter-range competition in Europe.

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