



Containerisation, Box Logistics and Global Supply Chains: The Integration of Ports and Liner Shipping Networks

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In 2006, container shipping celebrated its 50th anniversary as an innovation that had a tremendous impact on the geography of production and distribution. Production became globalised by a better usage of comparative advantages while distribution systems were able to interact more efficiently. This paper analyses the mounting pressures on box logistics in light of global supply chains. It will be demonstrated that the basic principle of containerisation remained the same notwithstanding scale increases in vessels and terminals and a clear productivity increase in container handling. Although the container was an innovation initially applied for maritime transportation, the emergence of global supply chains has placed intense pressures to implement containerisation over inland freight distribution systems. Box – containerised – logistics is increasingly challenged to deal with the ever-increasing time, reliability and costs requirements of global supply chains. Imbalances in trade flows and accessibility and capacity constraints are among some of the developments that are making it increasingly difficult to reap the full benefits of containerisation.

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INTRODUCTION

Looking back at 50 years of containerisation

In 2006, container shipping celebrated its 50th anniversary as an innovation that had a tremendous impact on production and distribution (Levinson, 2006). It is only with containerisation that production could become globalised by a better usage of comparative advantages while distribution systems were able to interact more efficiently, reconciling spatially diverse supply and demand relationships. Yet, even after half a century, the role of containers in global trade, production and distribution has not been much acknowledged outside groups of academics and practitioners closely related to maritime shipping, rail freight, terminals and logistics.

Container volumes around the world have witnessed tremendous growth in the last 50 years, with an accelerated growth since the mid-1990s. According to UNESCAP (2005), the total number of full containers shipped on worldwide trade routes (excluding transshipment) amounted to 77.8 million TEU for the year 2002, compared to just 28.7 million TEU in 1990. In 2015, the volume is expected to reach 177.6 million TEU. Volumes on the east–west trades (ie Transpacific, Transatlantic and Asia/Europe) and north–south trades are expected to increase at an average rate of around 6% per year. Intra-regional trades, however, are expected to show a significantly higher growth of around 7.5%, mainly as a result of booming intra-Asian trades, but also because of the setting of hub ports acting as points of transshipment for regional markets. Drewry Shipping Consultants (2006) estimates that the total throughput handled by the world's container ports (not to be confounded with the trade route volumes mentioned above) increased from about 236 million TEU in 2000 to an estimated 399 million TEU in 2005 (including empties and transshipment), representing an average annual growth rate of 11%. Transshipment traffic has been the driving force behind growth in container handling in the last decade. In 1980, total container throughput in world ports did not exceed 40 million TEU. In 1990, it reached 75 million TEU. As far as the near future is concerned, worldwide container handling is expected to increase further to 628 million TEU in 2010, of which 57% are port-to-port full containers, 14% are port-to-port empty containers and 29% are transshipment (Drewry, 2006).

In most developed regions around the world, the container has a high share in the maritime-related import and export flows of general cargo. Table 1 presents the containerisation degree in a number of European ports, expressed as the share of containerised cargo in total general cargo handled in the port (so dry and liquid bulk excluded since these commodities have shown limited potential so far, outside niche markets, to be containerised). The data point to a



Table 1: Degree of containerisation in a selection of European mainland ports (sorted according to degree in 2005)

in %	Country	1980	1985	1990	1995	2000	2003	2005
Hamburg	Germany	32.0	42.6	66.2	81.7	93.1	95.4	96.4
La Spezia	Italy	34.4	40.3	76.1	88.0	90.3	93.2	93.2
Le Havre	France	58.9	67.7	71.2	66.8	80.4	86.9	90.3
Algeciras	Spain	71.8	69.4	70.8	79.2	88.5	89.4	89.7
Leixoes	Portugal	22.0	28.7	37.1	63.5	75.4	85.1	87.7
Rotterdam	The Netherlands	57.4	65.8	69.9	73.9	77.7	79.1	83.1
Bremerhaven	Germany	35.6	47.1	58.7	73.4	81.9	82.9	82.8
Valencia	Spain	35.4	68.5	60.3	68.6	74.8	79.1	79.7
Antwerp	Belgium	21.5	29.0	38.0	50.9	64.8	75.0	77.6
Bordeaux	France	32.3	34.4	43.4	31.3	42.4	67.5	76.1
Thessaloniki	Greece	1.2	3.1	14.3	43.8	42.8	68.8	73.9
Barcelona	Spain	30.0	61.3	71.0	74.3	73.9	73.4	73.1
Lisbon	Portugal	32.2	47.3	58.0	65.8	69.5	72.9	72.0
Piraeus	Greece	20.4	36.5	45.8	65.3	74.8	76.3	68.6
Genoa	Italy	36.5	46.0	45.2	49.7	65.0	61.7	63.0
Bilbao	Spain	26.4	33.0	53.1	46.7	49.2	58.1	58.9
Marseilles	France	32.3	42.4	50.5	46.9	53.2	54.2	56.9
Zeebrugge	Belgium	30.6	22.5	23.3	30.0	41.5	51.0	55.0
Rouen	France	23.1	40.4	36.7	31.8	32.9	36.5	42.0
Amsterdam	the Netherlands	21.0	21.6	30.2	40.5	25.9	22.9	29.7
Trieste	Italy	34.4	46.7	55.4	28.9	27.4	18.8	29.6
Dunkirk	France	14.6	14.7	10.5	11.5	27.9	13.9	15.0
Zeeland Seaports	the Netherlands	11.1	10.0	4.4	3.1	2.3	4.3	4.3

Source: Calculations based on data of respective port authorities.

logistical curve of diffusion that is common for many technological innovations. Not all ports have embraced or were in a position to embrace containerisation. Early adoption appears to imply no guarantee of further containerisation. These findings are in line with the spatial models of Hayuth (1981), Barke (1986) and Notteboom and Rodrigue (2005) on the development of container port systems. Hence, these models suggest that not all ports, which invested early in container infrastructure, become major container centres. The resulting port concentration can cause degradation of minor ports in the network. Taking into account the 'degree of containerisability' (not all general cargo can be put in containers), it is expected that the worldwide degree of containerisation could reach a maximum of 75%.

Long-term patterns of international trade are influenced by product innovation and subsequent diffusion also in transport and logistics. The lifecycle theory suggests that all innovations are evolving following a pattern of a pioneering (or introduction) phase, a growth phase, a maturity phase, a saturation phase and finally a phase of decline triggered by obsolescence. This could ultimately lead to the disappearance of the initial innovation from the



market. The duration of each stage of the cycle varies with the type of innovation, the management supporting it as well as its level of market penetration. Nakicenovic (1987) demonstrated that the lifecycle theory can also be applied to transport modes and vehicle propulsion systems. Maritime transport by seagoing vessels and barges has always played an important role throughout history. We can refer to the many Chinese, Spanish/Portuguese, English and Dutch explorations aimed at setting up new trade routes (Fernandez-Armesto, 2006). In the second half of the 19th century, rail became the dominant mode of land transportation, but it was overtaken by road transport in the second half of the 20th century. In terms of propulsion, we evolved from sail and manpower to steam and, since the 20th century, diesel, gas and electric engines. However, improvements in maritime propulsion technology over the last half century implied marginal speed improvements, but significant cost and reliability ones.

Given the inevitable fact that all technologies have a lifecycle, the question arises as to what will happen to the container system as we know it in the decades to come, in particular when considering the requirements imposed on the system by global supply chains. Among the most significant questions that such an expectation puts forward are: what is the ultimate market potential of containerisation in terms of volume and market penetration (usage)? What shapes and structures in respective maritime and inland containerised freight distribution may this potential imply? When is a phase of maturity likely to be reached? What could seriously undermine future containerisation developments in terms of economic and technical issues? Although absolute answers to these questions cannot be provided, some elements shedding light on possible future development will be discussed.

Towards a phase of maturity

The container market, although still observing huge volume growth, is fast reaching a maturity phase characterised by a wide diffusion of the technology around the world and technical improvements that are more and more becoming marginal. Ships are getting larger and more efficient, but in essence the container technology driving the business altogether is basically the same as some 40–50 years ago. Shipping lines are deploying ever larger container vessels on the main trading routes driven by the promise of cost savings through achievement of economies of scale (at sea), as evidenced by Cullinane *et al* (1999), Lim (1998) and Notteboom (2004). The technical concept of a container vessel has not altered dramatically during the evolution from first-generation vessels to the latest ultra large container carriers of more than 10,000 TEU capacity (cf. Emma Maersk: LOA 397 m, beam 56.40, official capacity of



11,000 TEU). Economies of scale are likely to be pushed as far as it is technically and economically feasible.

Container terminals have witnessed a series of innovations aimed at improving quay and yard productivity. Container gantry cranes now have longer outreaches (up to 22 containers wide), more lifting capacity (ZPMC developed cranes with up to 120 tons of lifting capacity) and the spreaders have become more sophisticated (double lift, twin lift and tests by ZPMC for triple lifts). But again, the basic design of a gantry crane and spreader remained unchanged since the first developments by Sea-Land and Matsons in the early 1960s. The development of straddle carriers, RMG (rubber-tyred gantry cranes), RTG (rail-mounted gantry cranes) and other yard equipment really took off in the early 1970s. The use of AGVs (automated guided vehicles) is of more recent date, that is, a first application at Delta Terminal Rotterdam in the early 1990s. But here also, the basic principle remained unchanged: loading/discharging a container vessel (vertical movements) and stacking the containers one by one on the terminal (vertical/horizontal movements). Modern terminal equipment is becoming widespread and more standardised with the emergence of global terminal operators (HPH, PSA, APM Terminals and DP World, to name but a few) and with leading equipment manufacturers (ZPMC, Kalmar, Fantuzzi and others) having customers all over the world. This has made it increasingly difficult for terminal operators to achieve a competitive advantage solely through the terminal equipment used. Productivity gains have more than ever become a matter of terminal management skills (software and know how) and of course hinterland size instead of hardware.

Technology gains in equipment for moving containers inland are also becoming marginal. Push convoys have been around for quite some time now and although inland barges on the Rhine now reach capacities of close to 500 TEU, their design is quite standard (Notteboom and Konings, 2004). Rail shuttle technology dates back to the early days of containerisation and even the double-stack trains in North America were conceived as early as the 1980s (Thuong, 1989).

To summarise, the world is still embracing a decades-old concept – the container – to deal with the challenges of contemporary global supply chains. And although globalisation and the associated profound changes in worldwide manufacturing and distribution processes to a large degree have been made possible by containerisation, the same global supply chains are now exerting strong pressures on the container concept, leaving the players in container markets with quite some challenges.

To further support the growth of containerisation and to avoid a phase of saturation or even decline, major innovations are needed in the way in



which containerised logistics systems are managed. Smarter management of the container system and its related networks is a prerequisite for a sustainable deployment of the container concept in global supply chains in the longer term.

This paper thus analyses the mounting pressures on box logistics in light of global supply chains. The first section looks at the changing role of containers in global supply chains. The second part of this paper analyses to what extent existing liner service networks are adapted to cope with supply chain challenges in the medium and longer term. Ports and terminals are the central focus in the third section, while the fourth section discusses the mounting pressures on inland distribution.

THE ROLE OF CONTAINERS IN GLOBAL SUPPLY CHAINS

Logistics and the velocity of freight

Container shipping has changed the scale and scope of global freight distribution. By enabling a greater velocity in freight distribution, it has opened up new global markets for export and import as a greater quantity of space could be traded with a similar, if not lower, amount of time and often at a lower cost. This velocity is much more a function of time than of speed as containerisation mostly improved the function of transshipment (Rodrigue, 1999). Thus, it is not that freight is moving faster along the respective modes servicing supply chains, but that the efficiency of transport terminals has dramatically increased the velocity of transshipments and, consequently, of supply chains. The concept of transshipment here is taken in a large sense to include activities taking place when the freight is not in circulation, namely warehousing, which has adapted to provide a higher velocity to freight in the form of distribution centres. While prior to the introduction of the container, a standard break-bulk cargo ship could take weeks to be loaded or unloaded, a similar quantity of containerised freight can be transhipped in a matter of hours (Cudahy, 2006). It can be argued that the velocity of freight from a modal perspective has been achieved for more than half a century, but that containerisation, through the transshipment function, truly permitted a multiplying effect for this velocity. Once a specific velocity threshold is reached, a time-based management of production becomes a possibility as logistics moves from a push (supply-based) to a pull (demand-based) structure, reaping significant distributional benefits.

Containerisation has provided the mechanism to expand to international markets while improving the reliability, flexibility and costs of freight distribution. The convergence of these factors permitted the setting of global



supply chains, many based on the principle of 'just-in-time', which is an integration of the velocity of freight with production and distribution strategies.

Containerised global production networks

Global production networks (GPN) represent a functionally integrated network of production, trade and service activities that includes all the stages in a commodity chain, from the transformation of raw materials, through intermediate manufacturing stages such as assembly, to the delivery of goods to the markets (Henderson *et al.*, 2002; Coe *et al.*, 2004). Within this framework, GPN have made many manufacturers contemplate global logistics strategies rather than simply relying on conventional shipping or forwarding activities. Most actors in the transport chain have responded by providing new value-added services in an integrated package, through freight integration along the supply chain. Thus, it has become widely acknowledged that the functional integration of commodity chains goes beyond the function of manufacturing, but also includes governance and transportation (Gereffi and Korzeniewicz, 1994; Gereffi, 2001; Chopra and Meindl, 2001; Appelbaum, 2004; Rodrigue, 2006).

The competitiveness of GPN is to a large part determined by the performance of the logistics networks as they link production, distribution and consumption (Hesse and Rodrigue, 2004). These logistics networks are highly dynamic as a result of mass customisation in response to product and market segmentation, lean manufacturing practices and associated shifts in costs as production and distribution assets are repositioned within global supply chains. The container is at the same time a transport, storage and management unit. When embedded within GPN, the container becomes a production unit since it carries all the inputs of manufacturing as identifiable and manageable batches. Production and distribution thus become a matter of ensuring that containers – mobile inputs – reach the proper locations within a specified time range. Containerisation also levelled the competitive playing field for global manufacturing. Manufacturers who previously had limited access to the global market because of remote locations and lack of transport infrastructures realised that the ubiquity of the container as a global transport product is linked to a whole new set of opportunities. Through containerisation, all competitors have potentially the same level of access to an efficient and global freight distribution system through port facilities. Paradoxically, manufacturing clusters near major container terminals along the Chinese coast may have better accessibility to global markets than activities located in conventional central locations such as the American Midwest and the Western European Rhine/Ruhr deltas. Still, containerisation remains under-acknowledged in its role and function in supporting GPN (Hesse and Rodrigue, 2006).



In the following sections, we discuss the challenges to the world container system using a systems approach that will look consecutively to liner services, ports and terminals and inland distribution.

ARE THE EXISTING LINER SERVICE NETWORKS ADEQUATE?

Liner service networks in transition

With a growing complexity in global supply chains and networks, managing liner services has become a complex endeavour. Shipping lines design the networks they find convenient to offer, but at the same time they are bound to provide the services their customers want in terms of frequency, direct accessibility and transit times. This tension between routing and demand is important. The network planners may direct flows along paths that are optimal for the system, with the lowest cost for the entire network being achieved by indirect routing *via* hubs, some of the offshore, and the amalgamation of flows. However, the more efficient the network from the carrier's point of view, the less convenient that network could be for shippers' needs. Shippers could resent the indirect routes, opening the possibilities for other shipping lines to fill gaps in the market.

When observing recent developments in liner shipping, the productivity has been improved by using faster and larger ships and the devising of new operational patterns and cooperation between shipping lines. Some have suggested that the future of liner service lies in the equatorial round the world, following the beltway of the world (Ashar, 2002; De Monie, 1997). This service pattern focuses on a hub-and-spoke system of ports that allows shipping lines to provide a global grid of East–West, North–South and regional services. The large ships on the East–West routes will call mainly at transshipment hubs where containers will be shifted to multi-layered feeder subsystems serving North–South, diagonal and regional routes. Some boxes in such a system would undergo as many as four transshipments before reaching the final port of discharge. There are, however, a number of conditions that need to be satisfied before this scenario is feasible. The scenario assumes a cumulative growth of container traffic of 5%–6% per year in the next 15–20 years, sufficient concentration on the supply side of maritime container transport (mergers and acquisitions) and avoidance of measures that prohibit or impede the deployment of plus 10,000 TEU ships. New types of container terminal are needed at a minimal deviation distance from the main axial East–West route. As such, some of the current 'regional' hubs can develop in the next 10–15 years into 'global hubs'.

The establishment of a high degree of connectivity between the North–South and the East–West services is also a prerequisite for the realisation of this



scenario. This connectivity will contribute to an increase in the density of the goods flow on the main trade route and will consequently lead to higher service frequencies. Only a handful of lines have built relay networks that effectively involve the full integration of trade routes. Maersk Line is a prime example. The post-Panamax ships deployed on its pendulum services not only provide slots on the Far East and Europe/North America but also act as a conveyor belt between a series of controlled hubs – notably Algeciras, Salalah and Tanjung Pelepas. Virtually all the carrier's cargo to/from West Africa moves through Algeciras, from which weekly loops radiate. Most of these loops are 'double loop' or mini-pendulums. The main difference between Maersk Line relaying and that of many other carriers is the close integration of all parts. Different services dovetail to provide smooth connections, and operations at the main hubs are effectively under its control. The only other liner operator to have made serious steps in this direction is MSC, which has several firmly established relay services, and has launched several mini-pendulums (eg on the west Australia/Singapore/Thailand route). Mini-pendulums not only give extra direct services, but offer a safety valve in case of delays. For the strategic alliances and groupings (Grand Alliance, New World Alliance, etc), such a strategy is unlikely, given the different priorities of the members. Few dedicated relay services have been started under joint banners, and integrated operations in the Maersk Line mode are unlikely.

The concept of an equatorial round-the-world system might have its merits, but we argue it will be an addition to, not a replacement of, existing systems. Shipping lines have a wide range of patterns at their disposal, all of proven merit under particular circumstances. In the future, shipping lines will continue to mix triangle services, pendulum services, butterfly services, conveyor belt services and other forms of varying complexity with line-bundling services (loops with a limited number of direct port calls) and simple end-to-end services, and adapted for both mainhaul and relay services to create a network best fitting a carrier's requirements. This growing complexity in liner service networks is in line with the findings of Robinson (1998). In referring to the Asian hub/feeder restructuring, he argues that a system of hub ports as main articulation points between mainline and feeder nets is being replaced by a hierarchical set of networks reflecting differing cost/efficiency levels in the market. High-order service networks will have fewer ports of call and larger vessels than lower order networks. Increasing volumes as such can lead to an increasing segmentation in liner service networks and a hierarchy in hubs. Hub-and-spoke systems are just a part of the overall scene.

There is no 'one size fits all' approach to the future of liner service networks. The port hierarchy is determined by the decisions of individual container shipping lines (operating as independent carriers or in groupings)



thereby guided by strategic, commercial and operational considerations. The decisions of these lines regarding the hierarchy of the ports of call are rarely identical. Hence, a port may function as a regional hub for one liner operator and as a feeder port for another. The network function of a container terminal might also change. Ports serving long-haul mainline services could be degraded to feeder ports. Alternatively, a shipping line might decide to turn a regional port into a major interlining hub.

Schedule integrity issues

A major threat to the future of complex liner service networks lies in increased schedule unreliability. Low schedule integrities can have many causes, ranging from weather conditions, delays in the access to ports (pilotage, towage, locks, tides) to port terminal congestion or even security considerations. Notteboom (2006) demonstrated that port terminal congestion is currently the main cause of schedule unreliability by far. A low berth and or crane availability leads to disruptions in the liner service schedules of shipping lines. Given the nature of many liner services (more than one port of call, weekly service, hub-and-spoke configurations, etc) that are closely integrated, delays in one port cascade throughout the whole liner service and therefore also affect other ports of call (even those ports that initially had no delays). A low schedule integrity is a serious challenge for terminal managers as their planning tools (yard planning and ship planning software such as COSMOS and NAVIS) can only work optimally when the ship arrivals can be forecasted rather accurately (based on allocated slots). In case of serious congestion, terminal planning tools have their limitations and even a system of time slots does not work in practice. Table 2 provides an overview of the average schedule integrities on trade routes. For example, on the Far East–Europe trade, only 44% of the vessels made it according to their schedule. Among the late arrivals, 50% was one day late, 20% two days late, roughly 10% three days late and the remaining 20% four or more days late. Maersk Line recorded an average worldwide schedule integrity of 70%. MSC is among the poorest performers, with only 41%. MSC keeps time buffers relatively low and tries to solve resulting problems *via ad hoc* changes to the order of port calls, the *ad hoc* transshipment of containers at relay ports in the Mediterranean and the seemingly random skipping of one or more ports of call during a round voyage. Alternatively, Maersk Line is more strict in respecting the scheduled times and the order of ports of call. Time buffers are sufficiently high to cope with unexpected disruptions.

It is expected that the issue of schedule unreliability will become even more important in the future, as liner service networks are becoming more complex, container volumes surge and new terminal capacities in some parts of the world do not come on stream in time. Under such circumstances, guaranteeing a high



Table 2: Schedule integrity of liner services on specific trade routes

Schedule reliability per trade route – April–September 2006

Trade route	Percentage of on-time vessel arrivals ¹ (%)
Asia/East Coast South America	46
Asia/Europe/ Med	44
Asia/Indian Sub/Mideast/Red Sea	62
Asia/Africa	43
Europe/Med/Africa	41
Europe/Med/Aus/New Zealand	31
Europe/Med/Caribbean/Central America	67
Europe/Med/East Coast South America	62
Europe/Med/Indian Sub/Mideast/Red Sea	46
Europe/Med/North Coast South America	44
Europe/Med/West Coast South America	24
North America/Africa	50
North America/Aus	56
North America/Caribbean/Central America	37
North America/East Coast South America	38
North America/Indian Sub	76
Transatlantic	53
Transpacific	63
Total	53

¹Ship arrives at the port of destination on the scheduled day or on the day immediately before the scheduled day of arrival.

Source: Based on Drewry (2006).

schedule reliability and a high transit time reliability to global supply chains will have an ever higher price (eg more ships need to be deployed on a loop) and this could have an impact on freight rates and on supply chain efficiency. Vessel delays compound to delays in inland freight distribution. It also indicates that several improvements in the time performance through logistics and better inland strategies are yet to be seen.

Managers in the logistics industry are already spending a growing share of their time handling freight transport missteps and crises, partly due to a low schedule reliability. Reliability and capacity issues have emerged as critical factors next to pure cost considerations. Accepting a continuous high level of schedule unreliability as the new normal might in the longer term have adverse effects on the whole logistics system and eventually also on global production and consumption networks.

Towards new intercontinental shipping routes

Parallel to the strategies of establishing equatorial round-the-world container services, a set of circum-hemispheric routes around the northern hemisphere



are also a possibility, particularly since it is along this hemisphere that the bulk of the world's economic activity is taking place. This strategy would integrate a sequence of maritime and land (rail) transportation corridors in a seamless fashion. A continuous and bi-directional transport chain across a hemisphere is thus established. However, such a corridor does not yet exist and is likely to be decades away, but the North American landbridge segment has been operating for more than 20 years. The Northern East-West Corridor (NEW) linking the Atlantic with the Pacific through the transsiberian has been in the design phase for many years. The beginning of the 21st century has, however, brought renewed interests for the NEW corridor, especially with the booming Asian trade and the increasing pressure to ship containerised freight in a time-sensitive manner over long distances (Figure 1).

A complementarity could thus be established between the equatorial corridor, which will be mostly a maritime segment, and the north hemispheric corridor involving land and maritime segments. While the north hemispheric corridor would have less capacity, particularly along its trans-Siberian leg, it would provide a faster long-distance service than the equatorial corridor, servicing supply chains that are more time dependent. Shippers would thus pay a premium to use this faster route, which would be reflected in the commodities in circulation. The upgrade of the Panama Canal to larger dimensions is also

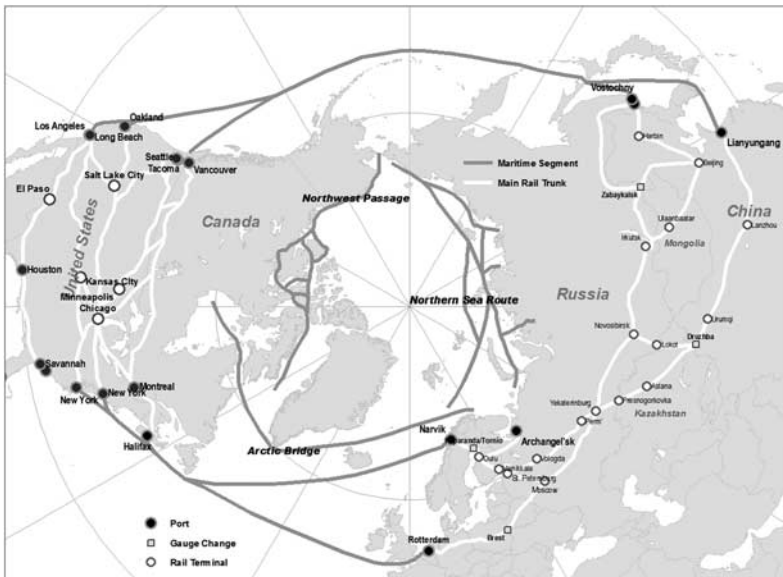


Figure 1: The northern circum-hemispheric routes.



likely to trigger an additional impetus to transcontinental shipping, making the equatorial corridor even more time (faster transit time) and cost (economies of scale) efficient. In the long run, and subject to controversial issues about global climate change, an arctic circum-hemispheric maritime corridor could also be established, thus setting three latitudinal corridors of circulation. Consequently, many opportunities in terms of production and distribution are likely to arise with the setting and operationalisation of long-distance trade corridors.

CAN PORTS AND TERMINALS COPE?

Growing container trade, larger vessels, new liner service configurations and new long-distance trade corridors challenge container terminals. By 2010–2015, the performance requirements for a global hub and gateway terminals on main-line vessels will typically take the shape of: (a) a sustainable ship output of 5,000 moves per 24 h, (b) a sustainable ship-to-shore gantry crane output of 40 moves per gross hour, (c) a ratio working time to time at berth of 90%, (d) an average number of gantries operating per main-line vessel of six and (e) an annual throughput per berth of 1.5 million TEU. A 10,000 TEU vessel with only three ports of call in Europe implies an average number of moves of about 6,600 TEU (loading and discharging) in each port of call. Such volumes pose huge demands on container crane density (number of cranes per vessel), on yard equipment and on the required stacking area. The associated peaks make the hinterland transport issue more complicated.

Rising environmental and social concerns related to terminal development, backed up by complex environmental legislations that do not always guarantee legal certainty to port/terminal developers, result in time-consuming and complex planning processes (Notteboom and Winkelmanns, 2003; Dooms and Verbeke, 2006; Van Hooydonk, 2006). As such, a breeding ground is formed for an ever-slower adaptability/responsiveness of the physical infrastructures to changes in port demand and associated cargo flows. Table 3 points to considerable delays in the planned opening of terminals and the actual opening of the container handling facilities. This issue becomes particularly acute when a paradigm shift towards supply chains takes place. Seaports are on the verge of becoming scarce goods. Port congestion along the US West Coast and in many European ports, such as in the summer of 2004, demonstrated how scarcity of port facilities and intermodal throughput capacity can impact a broader economic system. Scarcity in markets can lead to more efficient use of resources, which is positive in the long run. But a sustained high level of scarcity can in the longer term negatively affect the out-of-pocket and time costs related to the transport of goods in global supply chains.

**Table 3:** Delays in the planning process – some cases in Northwest Europe

	Development of initial plans	Proposed date for start operations (first phase)	Actual or earliest date for start terminal operations
Le Havre 'Port 2000' – France	1994	2003	2006
Antwerp – Deurganck Dock – Belgium	1995	2001	2005
Rotterdam – Euromax Terminal – the Netherlands	2000	2004	2008
Rotterdam – Maasvlakte II – the Netherlands	1991	2002	2013/2014
Deepening Westerscheldt ¹ – the Netherlands/Belgium	1998	2003	2008?
Wilhelmshaven/JadeWeserPort – Germany	n.a.	2006	2010
Cuxhaven – Germany	n.a.	2006	Never
Dibden Bay – UK	n.a.	2000	Never
London Gateway – UK	n.a.	2006	2009
Bathside Bay – UK	n.a.	2004	2008
Felixstowe South – UK	n.a.	2006	2007
Hull Quay 2000/2005	n.a.	2000	2007

¹Nautical access to the port of Antwerp.

Scarcity of terminal capacity can, however, also open prospects for new cargo routing patterns using new gateway concepts. On the one hand, terminal developments outside dominant container port regions can contribute to a more even distribution of containerisation in port systems around the world (option C in Figure 2). For example, congestion in LA/Long Beach provided the incentive to start considering the development of container facilities in Prince Rupert, Canada and Ensenada, Mexico. On the other hand, new terminal initiatives in the vicinity of established container gateways can trigger the formation of *multi-port gateway regions* that offer flexible cargo and vessel routing solutions to shipping lines, logistics players and shippers (option D in Figure 2). For example, the development of JadeWeserPort in Wilhelmshaven (Germany) will add to the value propositions of existing load centres in Hamburg and Bremerhaven. The container terminal initiatives in Amsterdam and Flushing aim to multiply the routing options available to cargo moving through the Rhine-Scheldt delta port system, a multi-port gateway region now dominated by Rotterdam, Antwerp and to a lesser extent Zeebrugge. The expected rising importance of multi-port gateway regions as a model serving global supply chains is further supported by the observation that shipping lines are not putting all their eggs in the same basket, and hence a multi-port gateway can offer an opportunity for a port operator to enter a regional market by using a new terminal/port outside the 'stronghold' of a competitor (eg Singapore/Tanjung Pelepas). The above factors could, in the longer term, lead to new

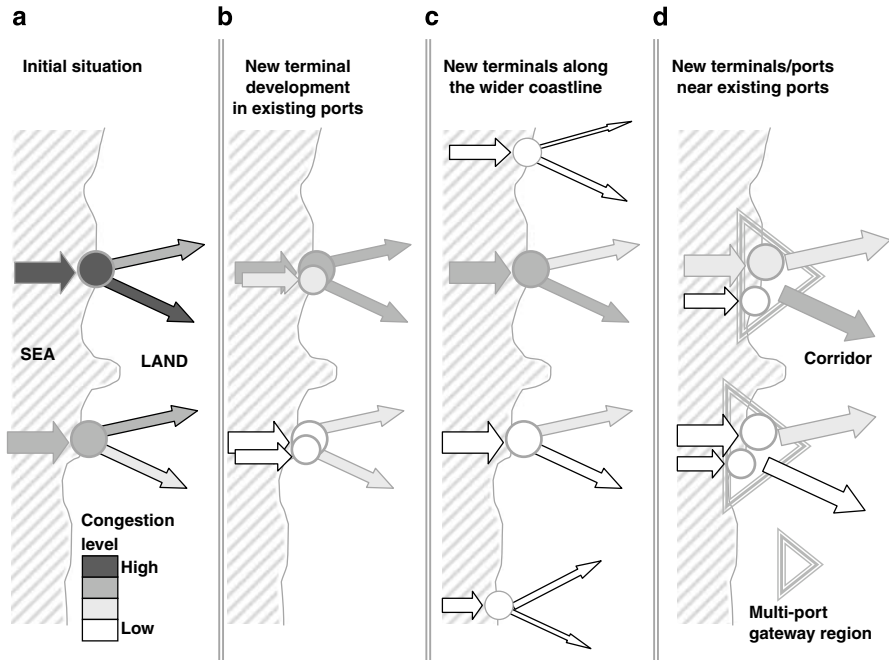


Figure 2: Terminal development options to ease congestion/capacity problems in a port system.

port hierarchies and a multiplication of the number of ports engaged in containerisation.

ARE THE MOUNTING PRESSURES ON INLAND DISTRIBUTION MANAGEABLE?

Pressures on inland distribution

The current development and expansion of intermodal transportation relies on the synchronisation of different systems of circulation as well as of different geographical scales. But when the synchronisation level increases, the maritime/land interface as a whole becomes more vulnerable to disruptions. For instance, if a segment in the container chain does not work efficiently in a highly synchronised environment, then the whole chain will be affected, triggering unforeseen consequences in time-dependent GPN. This leads to extra costs to find alternative routes, which, from a maritime standpoint, does not present too many difficulties as this simply involves new port calls along existing pendulum routes. However, for port terminals and particularly for



inland distribution systems, new routings and new volumes are much more difficult to accommodate. There have thus been mounting pressures on inland freight distribution to cope with the growth of maritime containerised shipping.

The future is likely to bring attempts to cope with three particular geographical scales. At the continental level, the setting of high-capacity long-distance corridors will continue to offer a viable option for long-distance container movements. Regionally, the process of integration between maritime and inland transport systems will lead to a number of penetration and modal shift strategies where each mode is used in its most cost- and time-effective way. The conventional representation of a hinterland, often linking the clients of the port with a distance decay perspective, is being replaced with one where spatial discontinuity and clustering prevails, but that is more functionally integrated, and locally, on-dock rail facilities where containers are exiting/entering a port terminal on rail instead of on truck, with the destination of these rail shipments often going much further inland. The 'Agile Port' concept is an expansion of this strategy by linking directly on-dock rail or barge facilities to a nearby inland terminal where containers can be sorted by destination. These configurations can ease the pressure on deepsea container terminals by moving the sorting function inland, thus increasing the efficiency of existing terminal facilities and the overall throughput. In all cases, the future of containerisation will largely depend on the land side, particularly on efficient intermodal and transmodal operations.

Imbalances and repositioning

With the emergence of global trade imbalances, ports and inland transportation are facing acute pressures to cope with disequilibrium in container flows. The repositioning of empty containers is becoming a key logistical challenge, particularly in North America where imbalances are taking on dramatic proportions; containerised exports have simply not kept pace with imports. For the United States, this implied an imbalance that totalled 11.1 million TEU with Asia and Europe in 2005. The outcomes are rate imbalances across the Pacific as it costs more per TEU for westbound flows than for eastbound flows, making freight planning a complex task for container shipping companies. About 70% of the slots of containerships leaving the United States were empty in 2005 (Boile *et al*, 2006). In recent years, containerised freight flows between Asia and Europe have become three times as voluminous as containerised flows between Europe and the United States. Thus, production and trade imbalances in the global economy are clearly reflected in physical flows and transport rates. The impacts on the geography of maritime transportation are major, requiring a re-assessment of their strategies in terms of port calls and hinterland transportation.



As such, the repositioning of empty containers is one of the most complex problems concerning global freight distribution. The major causes of this problem include, as previously stated, trade imbalances, but also repositioning costs, container manufacturing and leasing costs and usage preferences (Notteboom and Rodrigue, 2007). Trade imbalances are a macro-economic factor that maritime transportation is forced to address by repositioning empties at the transatlantic and transpacific scales. This ties up existing distribution capacities, particularly for long distances. Repositioning costs include a combination of inland and international transport costs. If they are low enough, a trade imbalance could endure without much of an impact as containers become repositioned. A large number of shipping lines use containers as a way of branding the company name. This observation, combined with the reluctance of shipping lines to share market information on container positions and quantities, makes it very difficult to establish container pools or to widely introduce the grey box concept. Many strategies are attempted to cope with repositioning issues. For instance, a large amount of transloading from maritime (40 footers) to domestic (53 footers) containers takes place in the vicinity of the ports of Los Angeles and Long Beach. It confers the added advantage of transferring the contents of three maritime containers into two domestic containers, thus reducing inland transport costs and justifying additional transloading costs.

Port regionalisation

Changing port–hinterland relations have a clear impact on port development patterns. The performance of seaports is strongly entwined with the development and performance of associated inland networks that provide access to cargo bases in the hinterland. Load centres are only as competitive as the inland and relay links that connect to it. To reflect changes in port–hinterland dynamics, Notteboom and Rodrigue (2005) introduced a regionalisation phase in port and port system development.

Regionalisation expands the hinterland reach of the port through a number of strategies linking it more closely to inland freight distribution centres. The phase of regionalisation brings the perspective of port development to a higher geographical scale, that is, beyond the port perimeter. The port regionalisation phase is characterised by a strong functional interdependency and even joint development of a specific load centre and (selected) multimodal logistics platforms in its hinterland, ultimately leading to the formation of a regional load centre network or logistics pole (Figure 3). The port system consequently adapts to the imperatives of distribution systems as supply chain management strategies finally permeate to transport operations and transport infrastructure.

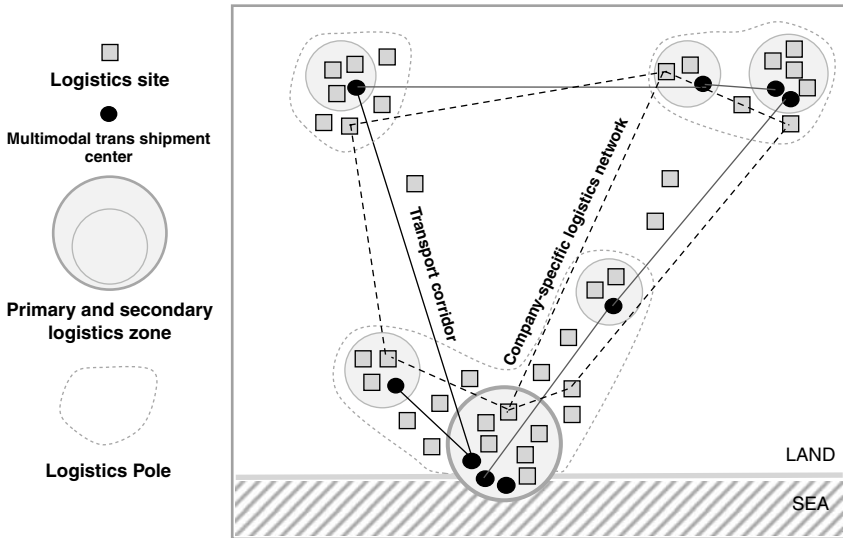


Figure 3: Port regionalisation and the development of logistics poles.

An important driver for the creation of regional load centre networks and logistics poles relates to the requirements imposed by global supply chains. No single locality can service efficiently the distribution requirements of a complex web of activities. Port regionalisation permits the development of a distribution network that corresponds more closely to fragmented production and consumption systems.

The transition towards the port regionalisation phase is a gradual and market-driven process that mirrors the increased focus of market players on logistics integration. In the regionalisation phase, it is increasingly being acknowledged that land transport forms an important target for reducing logistics costs. The responses to these challenges go beyond the traditional perspectives centred on the port itself. Regionalisation as such provides a strategic answer to the imperatives of the inland distribution segment of the supply chain in terms of improving its efficiency, enhancing logistics integration and reducing distribution costs.

Another factor having a major impact on port development dynamics are local constraints. Ports, especially large gateways, are facing a wide array of local constraints that impair their growth and efficiency. The lack of available land for expansion is among one of the most acute problems, an issue exacerbated by the deepwater requirements for handling larger ships. Increased port traffic may also lead to diseconomies as local road and rail systems are



heavily burdened. Environmental constraints and local opposition to port development are also of significance. Port regionalisation thus enables to partially circumscribe local constraints by externalising them.

Many ports around the world are reaching a stage of regionalisation in which market forces gradually shape regional load centre networks with varying degrees of formal linkages between the nodes of the observed networks. One of the problems that port authorities are facing relates to the infrastructural part of the port regionalisation phase. Port authorities try to enhance the intermodal capacity of the port with a heavy reliance on the performance of infrastructures and transport services. However, the manoeuvrability offered to port authorities seems to be restricted. First of all, the hinterland infrastructure level is dominated by public authorities who have to take into account social and political aspects and financial limitations in the decision-making process. Second, the logistical hinterland is dominated by market players, which, under normal circumstances, do not have to give account to the port authority. The powers of port authorities in developing hinterland infrastructure are thus limited. In most cases, the role of the port authority is restricted to initiator and facilitator of the necessary infrastructures that should guarantee a maximum of land accessibility in relation to the logistics pole.

Maritime gateways

The emergence of globally oriented container transportation systems reinforces gateways as major locations of convergence and transshipment. While intermodal transportation integrates different modes, gateways integrate different systems of circulation. Port regionalisation is thus a strategy used to improve the geographical connectiveness of gateways through a more flexible intermodal function. The maritime/land interface used to occur in a very specific part of the gateway; the port and its neighbouring warehousing and manufacturing clusters. Port regionalisation has not changed the function of gateways, simply the geographical space over which this function is taking place and its efficiency.

This perspective has, however, significant geographical variations in port regionalisation (Figure 4). In North America, long-distance trade corridors are servicing large markets; port regionalisation aims at reducing existing congestion and access the hinterland with new and more efficient alternatives, mainly through inland load centres accessible through rail. The inland system is highly clustered but with significant distances between those clusters once beyond coastal areas. In Pacific Asia and particularly in China, most of the manufacturing activities and logistics zones are directly adjacent to the gateways due to low hinterland accessibility: port regionalisation simply

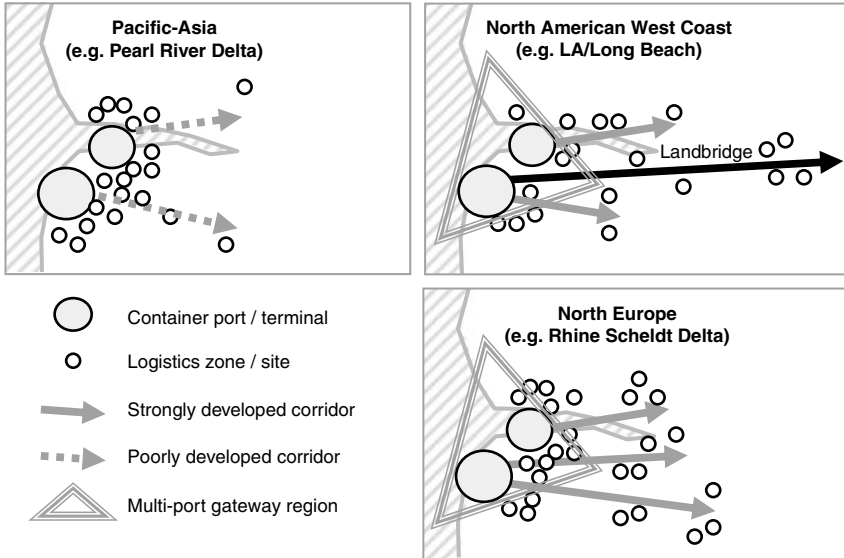


Figure 4: Gateways and the logistical hinterland.

involves the opening of new terminals that are diverting local truck flows. It is not a matter of accessing the hinterland, but ensuring that local/regional manufacturing clusters have the port capacity to support their export-oriented function. In the latter case, the port hinterland is simply a matter of manufacturers bringing truckloads to a nearby distribution centre that will be assembled in container batches that will then be sent to an adjacent port for export to global markets. In Europe, a mixture of both models can be found with some multi-port gateway regions, such as the Helgoland Bay ports in Northern Germany and the Rhine-Scheldt Delta in the low countries, combining vast European logistics zones in the vicinity of the ports with corridor-based access to distant hinterland regions (eg to Northern Italy). However, the distances involved are shorter due to the regional geography and transportation networks that historically have developed in a relatively independent manner.

CONCLUSIONS

The container system is slowly reaching maturity in a market environment where freight transportation has become the most volatile and costly component of many firms' supply chain and logistics operations. Managers have to deal with delays in the transport system, with rising oil prices, complex



security issues and with labour and equipment shortages and trade imbalances. Each of these problems adds risk to the supply chain, and the problems are likely to get worse before they improve. Managers in the logistics industry, including the port and maritime industry, are spending more and more of their time handling freight transport missteps and crises. As such, reliability and capacity issues have emerged as critical factors next to pure cost considerations.

These developments undermine the very fundamentals of the container system and urge market players and governments around the world to look for innovations in the way in which container flows and the associated logistics infrastructure are managed. Smarter management of the container system is a prerequisite for a sustainable deployment of the container concept in global supply chains in the longer term.

In this paper, we have pinpointed some critical factors in view of a sustained containerisation. With respect to liner shipping networks, it is expected that a multiplication of service network types (instead of a narrowing down to an equatorial multi-layer hub-and-spoke network) is likely to provide the best value attributes in dealing with global supply chains. The co-existence of different network types on the same trade route ensures flexibility in routing options and as such is likely to decrease network synchronisation and vulnerability problems in an era of increased schedule unreliability.

The availability of sufficient terminal capacity remains a major concern. It was demonstrated that rising environmental and social concerns related to terminal development have resulted in major delays in bringing new capacity on the market. Scarcity of terminal capacity can open prospects for new cargo routing patterns using new gateway concepts. We argue that the further development of multi-port gateway regions will become an ever more important element in offering both flexibility and service to global supply chains. This conclusion is in line with the findings of Gilman (1980), who rightly stated that the idea of one superport to serve a region is fictional. Gilman's motivation was based on operational aspects related to shipping networks. This paper added to this by including another dimension, that is, the requirements of global supply chains. The expected rising importance of multi-port gateway regions as a model serving global supply chains will result in new port hierarchies and a multiplication of the number of ports engaged in containerisation.

This paper also identified mounting pressures on inland freight distribution to cope with the growth of maritime containerised shipping. The problem of the repositioning of empty containers will continue to be a key logistical challenge. The future is likely to bring attempts to cope with three particular geographical scales. At the continental level, the setting of high-capacity long-distance corridors will continue to offer a viable option for long-distance container movements. Regionally, the process of integration between maritime and inland



transport systems will lead to a number of penetration and modal shift strategies (to rail and/or barges) where each mode is used in its most cost- and time-effective way. Locally, the concept of linking on-dock rail or barge facilities to a nearby inland terminal where containers can be sorted by destination is expected to become more important. Port regionalisation was identified as a key concept in driving the relationships between ports and inland freight distribution centres. Although significant geographical variations might develop throughout the world, the phase of regionalisation in all cases will bring the perspective of port development beyond the port perimeter.

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