The Future of Containerization: Perspectives from Maritime and Inland Freight Distribution

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Abstract

As containerization enters its peak growth years, its potential future developments over maritime and inland freight transport systems are being questioned. A series of issues can either further accelerate the adoption of containerization worldwide or, alternatively, could impose an upper limit to the extraordinary contribution that containers have implied for logistics systems and global commodity chains. These mainly include macro-economic, technical/operational and governance factors.

Future containerization will be largely determined by interactions within and between four domains ranging from a functional to a spatial perspective. The logistical domain involves the functional organization of transport chains and their integration in supply chains. The transport domain involves the operation of transport services and intermodal
operations. The infrastructural domain involves the provision and management of basic infrastructure for both links and nodes in the transport system. The locational domain relates to the geographical location of nodes and sites in the economic space and forms a basic element for their intrinsic accessibility in terms of centrality or intermediacy. It is underlined that the future of containerization will dominantly be shaped by inland transport systems.

Keywords: Freight Transportation, Intermodal, Transmodal, Maritime, Inland, Containerization.

INTRODUCTION

The past transformations brought by containerization bring the question about to what extent the container will continue to do so in the foreseeable future. For maritime containerized transport there is still a strong emphasis on economies of scale and the setting of shipping networks where pendulum services are interlinked with offshore terminals to improve market coverage as well as the frequency of services. For inland containerized transport, three issues are of particular relevance. One is port regionalization (Notteboom and Rodrigue, 2005), which implies a more efficient maritime / land interface, particularly with the usage of inland freight terminals with direct connections to the port through rail or barge services. A second concerns a new generation of inland terminals that will improve the productivity, efficiency and throughput of inland distribution. A third one involves the container itself in terms of new specification and more advanced forms of management.

The purpose of this article is to identify the macro-economic, technical/operational and governance factors that are likely to shape containerization in the next fifty years. It must first be acknowledged that an attempt at forecasting future trends is prone to inaccuracies in terms of the potential rate and duration of the growth process. Still, a few scenarios can be envisioned. Logistics will continue to put “soft” managerial and time based pressures on containerization but will underline a wide variety of strategies related to specific supply chains. While infrastructure investments will remain fundamental, maintaining and improving the velocity of freight in light of expected additional growth is likely to incite technical innovations at terminals, the
reconsideration of container sizes and maritime shipping networks. In light of these various changes, it is worth considering the future geographies of containerization that are likely to be set.

**Forecasting Future (Containerized) Freight Trends**

**Linear Thinking vs. Non-linear Processes**

Assessing future containerized freight trends in terms of volume and technology used for intermodal operations commands caution. Predictions and forecasting are often an exercise in futility, yet this exercise is constantly repeated even if it is systematically wrong. Behind the apparent rigor of many forecasting methods is often revealed a blatant oversight of the economic and technological reality of innovations and business cycles. Even more hazardous is the linear thinking often associated with extrapolations that involve non-linear systems. In many cases, the future is often seen as an extrapolation and a multiplication of existing trends and technologies. The paradigm shifts brought by new technologies and new economic conditions are not considered for the very good reason that they cannot be anticipated in full. Under such circumstances, forecasting commonly fails to be accurate and can be more a factor of misallocation of resources than a sound planning tool.

One of the most fundamental errors made when trying to forecast is to assume that economic systems behave like physical systems, implying that the level of prediction associated with physical systems can be replicated to economic systems. This mainly entails that the behavior is assumed to be constant and replicable to other contexts. While a retroaction in a physical system is often expected and predicted, a retroaction in an economic system often comes as a complete surprise (law of unintended consequences). This observation implies that the application of System Dynamics in an economic or logistics context would require utmost care. For instance, long term predictions either overestimate, underestimate or completely miss the point as they typically fail to capture paradigm shifts or structural shocks in the system.

An ex-post evaluation of past forecasts on container throughput evolution in ports learns that even the most advanced prediction models combining both quantitative and qualitative variables typically seriously
underestimated the actual container growth in the last ten years or so. For example, Coeck et al (1996) point to an underestimation of future container traffic in the European gateway ports of Antwerp and Rotterdam of at least 30% in a time span of about ten years.

**The Challenges of Forecasting Freight Transportation**

Trying to assess future freight transportation trends involves estimating concomitantly the volume, the networks set in place but also the routing of this containerized freight. Among the most important factor behind the difficulty to assess freight transportation lies in the macro-economic conditions of the global economy. Growth in GDP, industrial output and external (overseas) trade commonly feature as explanatory variables in forecasting models on maritime container flows. In the last decade or so, this has raised two fundamental issues. First of all, the net explanatory power of macro-economic variables is getting weaker. Second, the predictions on future container flows are increasingly hampered by the volatile nature of the macro-economic environment and the effects of turmoil in the financial markets on the asset economy.

The impact of China on the global economy and on trade flows has been substantial and yet the extent of its impacts has been systematically underestimated. Now that the “China effect” has been compounded into forecasting models, it becomes likely that future trends will be overestimated. Comparative advantages are shifting rapidly, leading to de-industrialization in North America and Europe, relocation and the re-industrialization of Pacific Asia. Trade flows have consequently become dislocated, creating an array of challenges for the freight transport industry (e.g. empty travel and inbound delays at gateways).

As the global re-organization of production, distribution and consumption is taking place, the relation between economic growth and growth of containerization is increasingly a dislocated one. The container system has become more than just a means to connect production to consumption centers, it is increasingly being associated with complex logistics networks supporting global production networks or GPN (Coe et al, 2004 and Henderson et al., 2002). The container transport system is entwined with the distribution patterns of value-added creation within logistics networks. This has given rise to the routing of containers via intermediate
places along land and maritime corridors. This development is exemplified by the emergence of container transshipment hubs in proximity of the main shipping lanes and the multiplication of inland terminal facilities supporting the creation of logistics zones. The renewed logistics organization has not only led to a surge in world container port volumes (cf. via the insertion of hubs), it has also given rise to the development of strong logistics regions, sometimes in places with a weak macro-economic profile.

Since freight transport companies are private entities that are profit seeking, they have a substantial flexibility in the allocation of their activities, which makes forecasting difficult since global business decision and various market strategies are concerned. The current trend involves taking control of several segments of the supply chain in order to reduce costs and risks, capture added value and insure a reliability of distribution. As such, freight transport companies decide which routes, modes and terminals their freight is going to take. There is an emerging role of multinational corporations (DP World, APM Terminals, Hutchison Port Holdings and PSA to name but a few) that are able to establish their own dedicated infrastructure networks, notably in terms of global port operators (Notteboom, 2002 and Olivier and Slack, 2006). In light of vertical integration strategies, shipping lines have entered the container handling market via the development of dedicated terminals at major load centers (Cariou, 2003). Both global terminal operators and carrier-operated terminals challenge conventional public policy dominantly based on infrastructure provision.

Freight transport markets are themselves very segmented, a reflection of the variety of economic sectors they service. There is a range of commodities, transport modes and stakeholders, each representing a specific but interdependent element of global commodity chains. An emerging dichotomy concerns cost-based versus time-based freight distribution systems, which favors a segmentation of the commodity chains servicing them. The segmentation also concerns the function of terminals. Classical economic geography associates transport terminals in general and seaports in particular with a break-of-bulk function (e.g. Dicken and Lloyd, 1990). With containerization, the terminal has adopted the role as a "break-of-container-cargo" location (Kuipers and Eenhuizen, 2004). The recent years have seen an impressive diversification of the value-added activities related to transport, ranging from negotiated rates,
inventory, transfer and supply chain management. For instance, integrators have emerged with the goal to mitigate and lessen supply chain costs for their clients in an intricate structure of bids and contracts with transporters, terminal operators and distributors. Variations in the cost structure of an element of the transport value chain thus have a greater chance to be mitigated. Value added activities also have a higher propensity to migrate along the supply chain and take place at locations that are deemed more suitable from a cost, but also from a taxation standpoint. Thus, segmentation in migration of added value activities are complex processes to consider in forecasting containerized freight trends.

**Growth Scenarios: Reaching Peak Growth and Maturity**

As containerization is heading towards of phase of maturity, it is worth considering the volume of containerized traffic this would entail. As previously discussed, providing such an answer is very hazardous in light of the wide variety of issues involved, ranging from technological developments, the decision making process of freight operators to macro economic considerations. The fundamental assumption is based on the replication of the logistical curve which assumes phases of introduction, growth and maturity, a pattern well known in the business and product life cycle theories. Looking at the history of transportation reveals that transport technology has consistently followed such a behavior (Ausubel et al., 1998), which can be inferred to containerization. Four major phases are considered (Figure 1):

**Adoption**: Mainly involved the early adoption of containerization by ports and maritime shipping companies. An arbitrary starting point is 1966 with the first transatlantic container services (or 1965 with the adoption of standard container sizes and lashing systems) until 1992 when the world container traffic reached 100 million TEUs. During that period a global containerized transportation system was gradually set in place.

**Acceleration**. The early 1990s clearly marked a phase of acceleration of containerization, particularly with the entry of China in the global sphere of production. This implied a growth of the volume of containerized traffic, which grew by a factor of three in a mere decade, as well as a fast diffusion of containerization in regions that were previously under-serviced. Meanwhile, an entirely new geography of container port
terminals emerged with new facilities built to service emerging manufacturing clusters as well as to strengthen existing gateways. A new centrasity, particularly in terms of production and a new intermediacy, particularly in terms of gateways and offshore hubs, was being put in place.

**Peak growth.** Coupled with a massive phase of globalization and the usage of containerization to support commodity chains, growth is currently reaching its maximal momentum. This places intense pressures on transport infrastructures to cope with this growth, which is also exacerbated by the emergence of strong imbalances in container shipping. Although peak growth appears to be the “golden era” of containerization, it is also plagued with capacity problems, externalities such as congestion and the potential of over investment due to expectations about future volumes.

**Maturity.** Implies that containerization has completed its diffusion, both geographically (within global markets) and functionally (within commodity chains). Under such circumstances, growth (or decline) is mainly the outcome of changes in the level of economic activity.

**Figure 1:** World Container Traffic, 1980-2008 (Drewry Shipping Consultants, 2007) and Projections to 2015
In 2008 worldwide port container throughput is expected to reach about 535 million TEU. Two possible scenarios about the development of containerization in the subsequent phase of maturity can be inferred:

The first scenario entails an ongoing growth of international trade at a rate similar to what took place in the last decade. It is a simply extrapolation of past growth trends. Peak growth would end around 2010 and be followed by a maturation of containerization. This would imply intensive deregulation in ownership, particularly over inland transportation, with further consolidation as well as rapid terminal development, at least doubling the capacity of most existing ports. This scenario, which assumes the doubling of container traffic between 2005 and 2015, raises serious questions concerning the amount of intermodal and modal infrastructures that would need to be brought online and the tremendous stress these volumes would have on inland transport systems and on the environment.

The low range scenario, a *divergence*, would entail a significant global recession where North American and European consumption suffers a setback. It is also linked with protectionism (particularly towards China) and higher energy prices. Although it tends to reflect a very negative economic environment, it could also take place in a context where the comparative advantages behind the push towards globalization that have prevailed until recently, are much less valid. Thus, a restructuring of manufacturing towards a more regional base can take place with lesser average distances involved for commodity chains.
Future containerization will be largely determined by interactions within and between four inter-related layers ranging from a functional to a spatial perspective (figure 2). The logistical layer involves the functional organization of transport chains and their integration in supply chains. The transport layer involves the operation of transport services (links) and intermodal and transmodal operations (nodes). The infrastructural layer involves the provision and management of basic infrastructure for both links and nodes in the transport system. The locational layer relates to the geographical location of nodes and sites in the economic space and forms a basic element for their intrinsic accessibility in terms of centrality or intermediacy.

**LOGISTICS: “SOFT” PRESSURES ON CONTAINERIZATION**

Logistics represents the “softest” element, but also the most fundamental, behind future containerized transportation. It is the most flexible and subject to rapid adaptation reflecting market changes. Since it concerns a wide array of activities, ranging from production planning to warehousing, logistical integration forces the resolution of many constraints in containerized freight distribution. Many of these involve time based components, including frequency, reliability and punctuality, which would not have been possible to mitigate at a global level without
containerization. As such, the container is increasingly seen concomitantly as a load, transport, logistical and production unit. The outcome is a segmentation of the market in terms of logistical requirements and the setting of niche markets in containerization. The integration of supply chains may convey a greater role to transport terminals as active buffers (negotiators) in supply chains.

### Logistical Characteristics of Goods

The mix of structural logistics factors related to containerized goods will determine the future development of the global container transport system, regional disparity in transport flows and with it the service requirements on transport operations serving specific routes (transportation level). As such, the logistics characteristics of goods will have an impact on operational decisions related to issues such as shipment scale, frequency and velocity and the associated infrastructural level. The main characteristics and their expected impacts are:

The average **value density** of containerized cargo expressed in value per cubic meter is expected to further increase, primarily on secondary routes. A similar development is expected with respect to the packing density (the number of boxes per cubic meter). The increase in value and packing density triggers an ever stronger focus on minimizing time costs and minimizing handling costs of a large number of small packages.

The **delivery frequency** is expected to increase as manufacturers and retailers seek to achieve even greater economies linked with low levels of inventory as well as time based distribution. This will come as a paradox between pressures towards economies of scale and high frequency shipments. For instance, larger container sizes, such as 48 or 53 footers, are preferred by shippers since they require less handling per TEU, while they may not necessarily be the right load unit for manufacturers abiding to JIT strategies. Thus, for long distance trade of final products to consumption markets where frequency is less an issue, the largest container size possible is preferred while for short distance movements such as between clustered production units a smaller load unit may be required.

Country-specific **products or packaging requirements** are likely to show a remarkable flexibility. While this function traditionally took place near final markets, depending on the structure of production (centralized vs.
multiple vertically integrated suppliers) and on the product’s type, it could move directly to the manufacturer or to intermediate locations. Conventionally, market specific packaging was performed at port of entry locations. Standardization and the setting of economic blocks, particularly for Europe, have expanded this range to a major continental gateway. This could pose a challenge to the development of logistical activities in import oriented regions such as Western Europe and North America.

The *share of transport costs* in total distribution costs will continue to rise due to a convergence of growing congestion, longer transport distances within supply chains as well as higher energy costs. The share of distribution costs in total production costs is determined by factors such as the future balance between global sourcing strategies and more local sourcing and the continued attractiveness of low cost countries in global supply chains.

*Technological and commercial dynamism* related to the containerized products is likely to increase. As the average shelf life (life cycle) of a vast array of containerized products is shrinking, more pressure is exerted on logistics structures in terms of high reliability, high responsiveness, short lead times and a high degree of flexibility. This might push a shift towards more decentralized logistics structures, but foremost towards more agile distribution networks offering a range of alternative routing possibilities tailored to the needs of the individual product batches and channeled through a complex network of supranational and regional distribution centers, cross-docking facilities and rapid fulfillment centers. The distribution focus will increasingly be measured in service requirements, instead of low costs.

Each individual product has a certain attribute with respect to these characteristics. The mix of these characteristics play a major role in the configuration of distribution networks both in terms of locations as well as functional divisions (e.g. where to do value-adding logistical activities). Next to logistics characteristics of products, also organizational factors will play a role for the future. The balance in market power between the different actors within the supply chain is of prime importance. When the power relation is dominated by the customer and the uncertainty of demand is high, the logistics structure will focus on responsiveness and flexibility. When the uncertainty of demand is low and the power relation
is dominated by suppliers, the dominant logistics requirement is reliability and centralization of supply.

**Containerized Global Production Networks**

The ongoing globalization of economic activities has led to the emergence of global production networks, which can be seen as functionally and geographically integrated commodity chains (Hess and Yeung, 2006; Rodrigue, 2006). By permitting a functional specialization of supply chains, containerization also permitted its spatial specialization. Thus, the functions of production, distribution and consumption can have an acute spatial differentiation while transportation maintains its cohesion in terms of frequency and reliability of deliveries (Hesse and Rodrigue, 2006). Within global production networks the container is concomitantly a transport, production, and distribution unit (Figure 3).

![Figure 3 Containerized Global Production Networks](image-url)

**Figure 3 Containerized Global Production Networks**

The transport function of containerization is well understood, notably intermodalism and the integration of different modes (Lowe, 2005). What is less understood relates to the whole new logistical paradigms brought by containerization on production and distribution. As the container became the privileged transport unit for international transportation, many production segments have embedded the container as a production planning unit with inputs and outputs considered as containerized batches. Concomitantly, the container became a distribution unit leading to radical changes in freight distribution with a switch to time-based management strategies. The shorter the transit time (which is not
necessarily proportional to distance), the lower the inventory level, which can result in significant cost reductions. The fact that the container is also its own warehousing unit has led to new distribution strategies.

**Transport: Sustaining the Velocity of Containerized Freight**

Logistical integration will put strong pressures on containerized transport systems to service its “soft” requirements with hard assets. Logistics management is strongly based on time and reliability considerations. However, these constraints must be met by adequate transport services, which imply changes in their nature and structure.

**The Velocity of Freight**

Transportation modes and terminals will continue to be hard pressed to improve the velocity of freight, which is more than simply the speed at which it moves along modes (the shipment speed). It also includes transshipment speed, which can be defined as the speed freight goes through intermodal operations (Figure 4). Since many transportation modes, particularly maritime and rail, have not shown any significant speed improvements in recent decades, an indication that a speed barrier may have been reached, intermodal operations have become one of the most important elements behind the increased velocity of freight. Containerization has been the fundamental factor behind such a radical change, as prior to containerization the shipment speed may have been adequate, but acute delays linked with inefficient transshipment prevented any forms of operational time management of freight distribution. In many transport chains, the velocity of freight has reached a level (logistical threshold) where time based management of distribution becomes a reality. This enables a move from push (supply based) to pull (demand based) logistics where the inventory is in circulation. It is very likely that any future improvements in the velocity of freight are solely going to be based on the function of transshipment, both from an intermodal and transmodal perspective.
Logistics also place pressures on containerization as a transport and management unit. The initial container sizes were the “20 footer” and the “40 footer”, which were agreed upon in the 1960s and became ISO standards. Initially, the “20 footer” was the most used. However, as containerization became widely adopted in the 1990s, shippers switched to larger container sizes, notably the “40 footer” as less transshipment movements per TEU were required. Since the current container dimensions were designed about 40 years ago, the changing operational environment has made the existing standard unsatisfactory in many ways. Economies of scale are obviously pushing towards the largest container possible as it implies for inland carriers little additional costs. For instance, carrying a 40 footer or a 53 footer container on rail mostly involves the same transshipment and capacity usage and thus the same rate. As a result, in many gateways along the North American West Coast, an active transloading function is taking place where the contents of three maritime containers of 40 foot are transshipped into two domestic containers of 53 foot.

The standardization issue is also drawing attention in Europe. The widespread use of Europallets (dimensions 80cm to 120cm) instead of ISO pallets (100cm to 120cm) on the European mainland has given rise to the deployment of pallet-wide containers with an inner width of 2.44m.
instead of the standard 2.34m. In order to further optimize unit loads, the European Union is supporting the development of the European Intermodal Loading Unit (EILU) with a capacity of 33 Europallets and a length of 13.2m compared to respectively 24 Europallets and 12.044m for a standard TEU. It is 18% smaller than the American 53 foot standard. The rationale behind this standard is to allow two European pallets to be placed in containers side by side. For European manufacturers and freight forwarders the existing ISO containers are based on North American pallet dimensions. While the new dimensions would still meet clearances for road and rail transport in Europe as well as abroad, the EILU is being strongly opposed by maritime shipping lines, because they have huge accumulated investments in current equipment and new ships under construction are optimized for current ISO container sizes. Since containers have useful lives of about 15 years, intermodal carriers are reluctant to adopt any new standard because of prior commitments in capital investment in modal and intermodal infrastructures.

There are thus pressures to change container specifications, mainly in terms of length, width and height. A variety of container sizes adds up to the logistical problems of allocating containers to specific slots on a ship. Port operators are in the same situation with capital investments in intermodal infrastructure. The eminent danger of divergence in container size would complicate the smooth transition of cargo from the maritime leg to landside logistics. Thus, fifty years of containerization has imposed operational standards that cannot be easily discarded.

Larger sizes confer economies of scale in loading, handling and unloading, which are preferred for long distance shipping as well as by customers shipping large batches of containerized commodities, but weight restrictions make the 20 footer suitable for ponderous goods such as grain. The same ship capacity would take in theory twice as much time to be transshipped if 20 footers where used instead of 40 footers. There is thus an evident rationale to use the largest container size possible, but the containerization of commodities will likely ensure that the 20 foot standard remains. “Hi cube” containers have also been put in use, notably since they do not require different handling equipment or road clearance. They are one feet higher (9’6”) than the standard 8’6” height and a 40 footer hi-cube container provides about 12% more carrying capacity volume-wise than its standard counterpart. Most North American double stack rail corridors can handle two stacked hi-cube containers, creating an
additional multiplying effect in terms of total capacity per rail car. In
Europe, the single stack limitations are improved with the usage of high
cube containers. The 53 feet hi-cube container is solely a domestic
container used in the United States. It has achieved preponderance within
the trucking and rail industries as it represents the largest load
permissible on the Interstate highway system.

Since China has an underdeveloped inland freight distribution system, the
tremendous capital investments that have been accumulated in terms of
intermodal transportation are likely to set the tone for the future
direction of containerization. Already, China manufactures most of the 53
footers and since that the China/United States trade relation is the most
important containerized trade relation in the world, the 53 foot standard
is quite a possibility but at least a decade away. Meanwhile,
containerization will have to cope with its existing limitations in container
size.

**Maritime Shipping**

Container shipping lines stride for market share and capacity tends to be
added as additional loops, implying large additional capacity. Lines
operate regular, reliable and frequent services and incur high fixed costs.
Once the large and expensive networks are set up, the pressure is on to
fill them with freight. Lines have come to accept that they have to take
whatever price is offered in the market. This acceptance has, in turn, led
to intense concentration on costs as well as razor thin profit margins.
Since the 1990s a great deal of attention has been devoted to larger,
more fuel efficient vessels, which produced substantial reductions in cost
per TEU of capacity provided (Cudahy, 2006, Cullinane et al, 1999, De
Monie, 1997 and Gilman, 1999). However, as vessels are now exceeding a
unit capacity of 10,000 TEU (the largest containers vessels afloat belong to
the fleet of Maersk Line and have an estimated carrying capacity of
13,500 TEU), further scale advantages at sea are becoming ever smaller
and diseconomies of scale at seaports become a major concern.
Moreover, the economies of scale did not necessarily translate into
reductions in cost per TEU carried. Hence, overall vessel and voyage costs
have been increased dramatically in order to establish competitive
networks satisfying the global requirements of the shippers. Carriers have
not reaped the full benefits of economies of scale at sea (Lim, 1998).
Lower slot utilization and the need to find more cargo at lower rates can
have a profound impact on carriers’ revenues and lead to lower profitability.

Economic and operational considerations will act as the ultimate barrier on vessel sizes and designs of the future. Although some shipping lines are now deploying vessels of more than 10,000 TEU, it is expected that this vessel size will not become the general standard. There are strong indications that the range of 6,500 to 8,000 TEU will reveal to be the most competitive vessel size as these ships offer more flexibility in terms of the number of potential ports of call and consequently the direct access to specific regional markets. In spite of increasingly marginal economies of scale for maritime shipping, larger vessel sizes are being introduced.

The evolution of containerization, as indicated by the size of the largest available containership, is a stepwise process (Figure 5). Changes are rather sudden and often correspond to the introduction of a new class of containership by a shipping company (Maersk Line tended to be the main early mover), quickly followed by others. Since the 1990s, two substantial steps took place, the first involved a jump from 4,000 to 8,000 TEU, effectively moving beyond the current limitations of the Panama Canal. The second step is currently unfolding and is likely to reach the 13,000-14,000 TEU level, which would essentially be a new Panamax level taking into account the proposed dimensions of the new Panama locks planned for completion in 2014. From a maritime shipper’s perspective, using
larger containerships is a straightforward process as it conveys economies of scale and thus lowers costs per TEU carried. From a port and terminal perspective, this places intense pressures in terms of infrastructure investments, namely maritime access routes and terminals. The surge in long distance trade as a result of globalization have favored the introduction of larger containerships as a mean to handle larger volumes, but the following elements are expected to strongly affect shipping lines’ considerations on further scale increases in vessel size:

The nautical profile of channels, maritime passages and rivers. When it comes to the dimensioning of the latest generation of ultra-large container carriers, it is becoming increasingly clear that large followers (e.g. MSC, COSCO and CMA-CGM) are not blindly following the path of early adopter Maersk Line. Their ‘wait and see’ approach has resulted in slightly shorter vessels compared to the Maersk giants (350-370m instead of the 396m of the Emma Maersk) while achieving nearly the same unit capacities. Their more compact size will make these vessels fit perfectly in the new Panama Canal locks (the Emma Maersk is oversized) and results in a better maneuverability on bendy rivers to major ‘must’ ports of call, e.g. the river Scheldt to Antwerp and the river Elbe to Hamburg.

The shift from a ship-based cost approach to a network cost approach. In a shipping industry already dominated by large vessels, mergers, acquisitions and strategic alliances, the potential cost savings at sea are getting smaller and the pressure to find cost savings elsewhere, i.e. in the field of landside logistics, is growing. Besides cost and revenue considerations, the demand pull force of the market is the main driving force for carriers to integrate their services along commodity chains. Carriers that have traditionally been concerned only with the transportation of goods from one point to another are now urged to seek logistics businesses in the area of just-in-time inventory practices, supply chain integration and logistics information system management (Graham, 1998, Evangelista and Morvillo, 1998 and Heaver, 2002). Shipping lines are increasingly evaluating their fleet mix in function of the ability to meet the logistics requirements of their customer base (i.e. price, transit time, schedule reliability, liner service frequency and proximity to markets).

The hub-and-spoke effect on size. The emergence of major offshore hubs favored a concentration of large vessels along long distance high capacity routes while lesser ports can be serviced with lower capacity ships.
Consequently, the emergence of offshore hubs has permitted liner services that would otherwise be economically unfeasible. However, there is a limit to the hub-and-spoke network configuration (as will be demonstrated in the next section) and consequently also to the size of the vessels being deployed on the trunk routes.

Overestimation of technical difficulties. Several technical aspects related to larger vessel size were a priori considered more challenging than they turned out to be. For instance, it was assumed that a vessel of the size of the Emma Maersk would require two propellers but a 80,000 kw engine was built and only one propeller was required. In anticipation of future growth of containership sizes, many port operators acquire portainers to handle widths of up to 22 rows of containers.

**Liner Shipping Networks**

In the last two decades increased cargo availability has made shipping lines and strategic alliances among them to reshape their liner shipping networks through the introduction of new types of end-to-end services, line-bundling services and pendulum services, especially on the main east-west trade lanes. As a result, a new breed of load centers has emerged for transshipping at the crossing points of trade lanes, i.e. hub ports involved in interlining and hub-feeder operations. Elsewhere, in particular in Northern Europe, North America and China, load centers remain mainly functioning as gateways between deepsea liner shipping networks and extensive intermodal inland networks. The organizational dynamics in liner service networks have a clear spatial impact (Figure 6). Most mainline operators running services stick to line bundling itineraries with between two and five port of calls scheduled in each of the main markets. Notwithstanding observed diversity in calling patterns, carriers do not select one mega-hub per region. The super port idea (Gilman, 1980) has thus not materialized.
The future spatial development of liner schedules will largely depend on the balance of power between shipping lines and shippers and the degree of required level of market segmentation. The higher the bargaining power of shippers vis-à-vis shipping lines the more pressure for direct calls as this will shift the ‘cargo follows ship’ principle to the ‘ship follows cargo’ principle. For example, shipping lines are massively prepared to call at the upstream ports of Antwerp and Hamburg in large part because of their high cargo generating performance and the savings they can make in onward inland transportation distances. The optimal liner network design is not only function of carrier-specific operational factors, but more and more of shippers’ needs (for transit time and other service elements) and of shippers’ willingness to pay for a better service. It is likely the future will bring a higher demand for service segmentation which will result in a multiplication of types of liner services serving an ever larger number of container gateways and hubs.

Transit times and variation in transit times remain major areas of concern for the liner shipping industry as shippers and logistics service providers are attaching greater value to service reliability and service speed. Liner service networks are suffering from schedule integrity issues, mainly caused by terminal capacity shortages and resulting port congestion in gateway regions particularly along the US West Coast and in the North.
European port range (Notteboom, 2006). Additionally, shipping lines face high fuel costs and have to comply with stringent regulations on the use of low sulphur fuel in waters in Europe and the US. For instance, bunker prices (380cst grade) in Rotterdam, one of the main bunker port in the world, have nearly doubled from US$ 155 in 2004 to about US$ 300 at the end of 2006 and reached peaks of more than US$ 700 in the summer of 2008. Most shipping lines have reacted by lowering the commercial speed of large container vessels from 23-24 knots to 20-21 knots, typically reducing the bunker consumption from 200 tons to 150 tons per day for an 8000 TEU vessel (ESPO, 2007 and Notteboom and Vernimmen, 2008). On the Europe – Far East route, the resulting savings in fuel costs have more than once partly or even completely been offset by the need of deploying an additional vessel in order to keep a weekly call in every port on the liner service route. Delays due to port congestion and high fuel costs are thus having a negative impact on both the transit times and schedule reliability on the major maritime routes.

Higher energy prices challenge the introduction of fast container vessels designed for carrying high-value goods on specific port-to-port itineraries. The most advanced project in this niche segment is Fastship Atlantic, a project aimed at introducing jet-powered container vessels with a capacity of 10,000 tons and a service speed of 38 knots on the route between Cherbourg in France and Philadelphia on the US east coast. With a port-to-port time of only 100 hours, projects like Fastship Atlantic want to exploit the void between high cost airfreight and low cost, but slow speed ocean services. As the success of such a liner service will greatly depend also on the port handling speed, the terminals at both ends of the Atlantic will use Automatic Guided Vehicles (AGVs), enabling a complete turnaround of the vessel within six hours of port arrival, versus up to 24 hours for traditional container cranes working on standard container vessels with a similar slot capacity (Fastship Atlantic website).

**Infrastructure: The Physical Bottom Line**

The expectations about future growth of containerized traffic will have to be matched by a physical reality of transport infrastructures. Thus, future developments for container terminals and their infrastructures will be geared more in terms of throughput than in terms of capacity. This
concept is more compatible with time based considerations imposed by logistics. Thus, “soft” logistical pressures eventually percolate to the “physical bottom line”. For many container terminals, increasing throughput and thus the productivity has become a challenge. The conventional strategy mainly involved the expansion of terminal facilities and the purchase of more efficient intermodal equipment. In many cases, lateral expansion of port terminals is no longer an option and the amount of truck traffic servicing the terminal is such that significant delays are experienced at the gate and on local access routes. Many inland terminals are also facing pressures to accommodate larger quantities of transshipments while dealing with location constraints. Both gateways and corridors, as high traffic locations, require additional throughput derived capacity to be brought forward.

THE CHANGING ROLE AND FUNCTIONING OF TERMINALS

The gradual shift from conventional break-bulk terminals to container terminals since the early 1960s brought about a fundamental change in the function and layout of terminals (Table 1). Conventional break-bulk terminals were mainly focused on direct transshipment from the deepsea vessel to inland transport modes. Direct transshipment is associated with very short dwell times (i.e. the average time the cargo remains stacked on the terminal and during which it waits for some activity to occur), requiring only a small temporary storage area on the terminal. The introduction of container vessels meant larger cargo volumes per port call and shorter handling times per ton. Both factors made direct transshipment no longer feasible as this would require a large amount of trucks, barges and trains to be in place during the vessel’s port stay. Containerization contributed to a modal separation on terminals. Each transport mode received a specific area on the terminal, so that operations on vessels, barges, trucks and trains could not obstruct each other. This modal separation in space was a requirement for setting up a system of indirect transshipment whereby each transport mode follows its own time schedule, i.e. modal separation in time. Under the indirect transshipment system, the terminal stacking area functions as a buffer and temporary storage area between the deepsea operations and the land transport operations that take place later in the process.
TABLE 1: CHARACTERISTICS OF CONVENTIONAL BREAK-BULK TERMINALS VERSUS CONTAINER TERMINALS

<table>
<thead>
<tr>
<th>Conventional</th>
<th>Container</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small terminal surface</td>
<td>Large terminal surface</td>
</tr>
<tr>
<td>Direct transshipment possible</td>
<td>Indirect transshipment</td>
</tr>
<tr>
<td>Limited mechanization and automation</td>
<td>Advanced mechanization and automation</td>
</tr>
<tr>
<td>Improvisation in terminal operations</td>
<td>Organization and planning</td>
</tr>
</tbody>
</table>

However, advances in logistics in the last decades gave a new meaning to the temporary storage on terminals. Instead of using the stacking area as a facilitator for a smooth synchronization between transport modes, shippers and logistics service providers started to use terminals as places for the cheap storage of goods. This change in the functional use of terminals implied that high dwell times at container yards were no longer an indication of a poor connectivity and synchronization between maritime operations and land transport. High dwell times got more and more associated with deliberate actions of actors in the supply chain who wanted to make maximum use of the free storage time offered to them by terminal operators. Terminals became cheap buffers in supply chains. In European main ports the average dwell time on container terminals ranges from 4 to more than 7 days, with most terminals offering a free storage time of around 7 days (Merckx, 2006). High dwell times are less of a concern when ample stacking capacity is available. However, with the present constant danger of container terminal capacity shortages in Europe and the US West Coast, terminal operators have come to realize that a generous free storage time could seriously reduce yard capacity as well as obstruct a seamless on carriage to the hinterland. The larger the number of containers in the terminal’s storage areas, the more likely the number of stacking and unstacking movements, the costs of which have to be assumed by the terminal operator.

Pricing strategies of the terminal operators have somewhat changed in the last couple of years: free time on the terminal has been reduced and
higher charges apply to containers that stay on the terminal for a longer period of time. However, not in all ports these charging systems have been effective in lowering dwell times. One reason is that charges remain rather low compared to the total logistics costs of the goods. Many receivers of the goods thus opt for cheap storage at the terminal instead of in their own warehouse or factory premises. An alternative strategy consists in transferring the temporary storage function to other nodes in the container network, primarily inland terminals and satellite ports.

It is very likely terminals will take up a more active role in supply chains in the future by increasingly confronting market players with operational considerations through imposing berthing windows, dwell time charges, truck slots, etc., all this to increase throughput, optimize terminal capacity and make the best use of the land. The more terminals become relatively scarce or capacity constrained, the stronger this trend towards a more active role of terminal operators.

**High Throughput Port Terminals**

A high throughput port concept aims at linking directly through a dedicated rail corridor on-dock rail facilities to a nearby inland rail terminal where containers can be sorted by destination. On one side, the maritime terminal increases its throughput, in theory up to 40%, without additional land, while on the other side, a nearby inland rail terminal facing less land pressures is used to sort containerized shipments to their respective inland destinations. A share of the cargo storage and sorting aspect of terminal operations is consequently moved inland where there is more land available and road terminal access is less problematic.

In such a setting, the inland rail terminal becomes a particularly important component of the system as its role becomes increasingly focused on transmodal (rail to rail) operations. Transloading operations should not be neglected, particularly in the North American setting. A maritime container can be picked up at the port terminal and trucked to a distribution center in the vicinity of the inland rail terminal. At the distribution center, the contents of three maritime containers (40 footers) can be transloaded into two domestic containers (53 footers) and then loaded on a freight train. This has the notable advantage of reducing domestic transportation costs since rail companies charge about the same rate for 40 and 53 footers. This also prevents long distance movements of empty maritime containers as they remain in the vicinity of the port.
“synergy” between the port and the inland terminal of such a concept creates a new type of maritime / land interface which essentially results in a regionalized port.

**Containerized Transmodal Operations**

Even if containerization has led to notable productivity improvements, particularly at maritime terminals, containers moving inland are subject to several undue delays. Although empirical evidence is hard to come by, a container being moved long distance by rail and road within the United States could spend as much as half the transit time immobile. Such delays are partially the outcome of capacity constraints but more importantly of inefficient intermodal and transmodal operations. Particularly, transmodal – within the components of a same mode – operations represent a field where substantial benefits could be realized in inland freight distribution. Because of market and ownership fragmentations that characterize large freight markets such as North America a transmodal movement is often required.

**The Maritime / Land Interface**

There is a clear trend involving the growing level of integration between maritime transport and inland freight transport systems. Until recently, these systems evolved separately but the development of intermodal transportation and deregulation provided new opportunities which in turn significantly impacted both maritime and inland logistics. One particular aspect concerns high inland transport costs, since they account anywhere between 40% and 80% of the total costs of container shipping, depending on the transport chain. Under such circumstances, there is a greater involvement of maritime actors (e.g. port holdings) in inland transport systems. The maritime / land interface thus appears to be increasingly blurred. Corridors are becoming the main structure behind inland accessibility and through which port terminals gain access to inland distribution systems. Since transshipment is a fundamental component of intermodal transportation, the maritime / land interface relies in the improvement of terminals activities along those corridors. Strategies are increasingly relying on the control of distribution channels to ensure an unimpeded circulation of containerized freight, which include both maritime and land transport systems.
The continuity of the maritime space to insure a better level of service takes different forms depending on the region. For North America, rail transportation has seen the emergence of long distance corridors, better known as landbridges. The North American landbridge is mainly composed of three longitudinal corridors and is the outcome of growing transpacific trade and the requirement to ship containerized freight across the continent. For Western Europe, barge systems are complementing trucking with inland waterways accounting for between 30 and 40% of the containers going through major gateways such as Rotterdam and Antwerp. Localized alternatives to improve inland distribution, such as the Alameda corridor, are implemented in addition to trans-continental strategies such as the existing North American landbridge and the planned Northern East-West Freight Corridor spanning across the trans-Siberian to the port of Narvik in Norway with an oceanic leg across the Atlantic.

**Locations: Future Geographies of Containerization**

The logistical pressures, the transportation networks and the infrastructures form a tangible reality in the locations they take place. A new geography of containerization has emerged and considers functional divisions in space in terms of origins, destinations and intermediate locations. Many terminal facilities are running out of options for their sites which has forced new geographical considerations and new forms of valorization within the locational layer. This valorization is particularly linked with the emergence of major gateways and hubs at intermediate locations. An intermediate location can imply a location near the main maritime routes such as for offshore hubs or near production and consumption centers such as for gateway ports. For gateway ports, a good location is a necessary condition for attaining a high intrinsic accessibility to a vast hinterland, which often builds upon the centrality of the port region.

**Containerization and Intermediacy**

The standard “break-bulk” intermediacy is being replaced by an intermediacy defined by offshore terminals. The conventional geography of container ports has been modified by the setting of offshore terminals
at new locations where the overall efficiency of maritime shipping networks is improved as containers can be transshipped at intermediate locations. These new locations have many locational advantages such as being at the intersection of major long distance shipping routes. The matter then becomes to select a port site in reasonable proximity, having sufficient depth, available land and favorable regulatory and labor regimes. Since most of them were established recently, offshore hubs are in full consideration (and often the only one) of the requirements of containerized maritime shipping as opposed to traditional ports for which containerization represented an adaptation. The insertion of an offshore hub within existing networks usually takes a hub-and-spoke or a relay structure. With a hub-and-spoke structure, the offshore hub provides an interface between regional and global shipping networks by acting as a point of collection and transshipment. With a relay structure, the offshore hub acts as an interchange between long distance corridors, which fits circum-hemispheric distribution strategies.

**Circum-Hemispheric Distribution**

As containerization reach a phase of maturity, the setting of a global “containerized highway” involving continuity between inland and maritime transport systems is expected (Figure 7). For the northern hemisphere where the bulk of the economic activity takes place, this would involve three major rings or circulation; the equatorial ring, the middle ring and the arctic ring. The equatorial ring can be perceived as a conveyor belt where high capacity and high frequency containerships are assigned and would interface with the middle ring at specific high throughput offshore hubs. The widening of the Panama Canal will improve the operational efficiency of the system, placing it on par with the capacity of the Suez Canal. Under such circumstances, the setting of true bi-directional and high frequency round-the-world services could finally take place. The most important, the middle ring, is composed of two large continental rail land bridges (North American and Eurasian) linked by transatlantic and transpacific connectors. It will require a full fledged maritime / land interface with major gateways and corridors. The arctic ring is problematic as a full ring of circulation, but specific maritime bridges could be established (e.g. Narvik - Churchill), which would complement the middle ring.
As containerization enters its peak growth years, various processes and trends are either accelerating the adoption of containerization worldwide or, alternatively, could impose an upper limit to the extraordinary contribution of containers to freight distribution and globalization. Below are several questions that remain to be answered.

A Growing Divide between Sea-based and Land-based Operations?
Containerization is confronted with a growing tension between a massification at sea and an atomization on land. Growing vessel size has led to the massification of unit cargo at sea. On terminals and at the landside, massification makes place for an atomization process whereby each individual container has to find its way to its final destination. Container terminals are feeling the full impact of this growing tension: current vessel handling techniques discharge and load containers one by one (two by two in case of twin lift), leading to long port turnaround time.
for the ultra large container carriers. A major challenge consists in extending the massification concept as far inland as possible. Postponing the atomization of container batches shifts the container sorting function to the inland and as such eases the pressure on deepsea terminals. High-volume rail and barge corridors including inland terminals play a crucial role in this process.

It could be argued that the changes taking place over inland freight distribution are thus likely to be more significant, both in scale and scope, than the changes over containerized maritime transportation. What will take place inland will shape the future of containerization in terms of its potential to further accommodate the growth of international trade. The reason is rather straightforward; because of the “first and last miles” are taking place inland. Whatever the maritime capacity, this throughput must be assumed by inland freight transport systems.

**A Multiplication of Routing Options?**

The future is likely to bring a multiplication of container routing options to comply with the demand requirements of local and regional markets and to allow logistics operators to benefit the most from operational factors. This will take the form of the setting of several rings of global circulation, from the circum-equatorial maritime highway supported by an improved Panama Canal to landbridges and their maritime connectors. At the level of regional distribution, several gateways and corridors may be competing to attract traffic by offering their respective mix of cost, time and reliability advantages. This is particularly the advantage that the new container facilities at Prince Rupert along the Canadian West Coast that opened in 2007 are capitalizing on; shorter time services to major inland North American destinations. A multiplication of routing options at sea and on land will make the container system less vulnerable to disruptions, thereby better meeting the reliability and capacity considerations of shippers.

**A Continuing Global Spatial Divide?**

The emergence of global commodity chains and the specialization of production have resulted in acute trading imbalances which are reflected in freight flows and the repositioning of empty containers. Will these imbalances and the disruptions they impose of maritime and inland shipping persist? This is unlikely since economic history underlines that
highly imbalanced trade structures cannot be maintained for a long period and that eventually a new equilibrium is reached. This is likely to imply a more regional structure of production and distribution.

An Evolution or a Revolution?
What would containerized transportation look like by 2056, the year of its one hundredth anniversary? A revolution would imply a significant paradigm shift in containerized freight distribution. Such a shift cannot be accurately predicted and its consequences can even less be assessed. Still, the future of containerization will be geared by commercial, technological and logistical forces. Commercial forces may point at a more regional focus of production, correspondingly shorter commodity chains and higher energy prices that will be internalized by freight distribution in one way (higher rates) or the other (economies of scale, modal shift). Technological forces are very difficult to assess as they may concern the modes, terminals and the container itself. The container will stay what it is; a simple box, maybe of different size, handled much more efficiently, but it will be a logistical box fully acting as a transport, production and distribution unit.

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