Chapter 10
International Maritime Freight Transport and Logistics

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For TRANSPORT GEOGRAPHIES: AN INTRODUCTION, Blackwell Publishing
Edited by Richard Knowles, Jon Shaw and Iain Docherty

Abstract

Maritime transport remains the dominant mode for international trade both for bulk transport of commodities and containerized break-bulk cargo. The economics of bulk transport still influence trade patterns and industrial location. Intermodal transport has become a global phenomenon as mechanized handling and containerization have reduced handling costs between modes and promoted their efficiency. Ports have become elements in global commodity chains controlled by logistics companies, maritime shipping lines, freight forwarders and transport operators. Their strategies and the allocation of their assets have shaped the structure of maritime transport networks in terms of ports of call, hierarchy and frequency of services. Post-Panamax container ships encourage pendulum services and the setting of high capacity inland corridors.

Keywords: Maritime Transport, Bulk, Containerization, Ports, Logistics.

1. Freight Transport, Maritime Transport and the Global Economy

A Changing Economic and Spatial Context

Few transport systems have been more impacted by globalization than freight transportation. Paradoxically, in a field dominated by passengers, freight remains fairly unnoticed by the general public, albeit manufacturers and retailers are keenly aware of the benefits derived from efficient distribution. In fact, the profit margin of many retailers and manufacturers is directly dependent on efficient distribution strategies encompassing a wide array of global suppliers. As such, in the last decades, international trade has systematically expanded at a rate faster than economic growth, an outcome of an international division of the production and massive accumulation of new manufacturing activities in developing countries. Maritime transportation is at the core of global freight distribution in terms of its unparallel physical capacity and ability to carry freight over long distances and at low costs. Aside from these well known characteristics, the maritime industry has substantially changed in recent decades. From an industry that was always international in its character, maritime transportation has become a truly global entity with routes that spans across hemispheres, forwarding raw materials, parts and finished goods. In fact, it is one of the most globalized industries around:

“A Greek owned vessel, built in Korea, may be chartered to a Danish operator, who employs Philippine seafarers via a Cypriot crewing agent, is registered in Panama, insured in the UK, and transports German made cargo in the name of a Swiss freight forwarder from a Dutch port to Argentina, through terminals that are concessioned to port operators from Hong Kong and Australia” (Kumar and Hoffmann, 2002, p. 36)
International maritime freight transport is composed of two main segments, the modes which are flexible in their spatial allocation, and the terminals, as locations, which are not. Shipping lines have a level of flexibility in terms of route selection, frequency and levels of service, but port terminals have a fixed capacity that if not used can imply serious financial consequences. Reconciling these two segments remains a challenge, particularly since the volume of maritime freight is steadily growing and since freight distribution is getting more complex as it services many origins, destinations and supply chains. Logistics has done a lot to reconcile the strategies of the maritime actors and in many cases shipping lines have taken matters into their own hands by investing directly in terminal facilities and securing access to hinterlands. Global port operators such as Hutchinson Port Holdings, APM Terminal, Port of Singapore Authority and Dubai Ports International are now managing terminal facilities in almost every single major port around the world.

The Enduring Relevance of Port Sites

Ports as locations where maritime and land traffic converges are crucial facilities in the global economy. There are more than commercial 4,500 ports around the world, but only a small share handle a significant amount of traffic (NGIA, 2005). The geography of these ports conditions the global geography of trade and flows since they are locations that cannot be easily by-passed. Ports remain points of convergence and divergence of traffic and their location is constrained by the physical characteristics of their sites. The first physical constraint involves land access and the second concerns maritime access. Both must be jointly satisfied as they are crucial for port operations and the efficiency of the maritime / land interface. Thus, poor land and maritime access can impair port operations and port development. However, maritime access is the attribute that can be mitigated the least. Activities such as dredging and the construction of facilities such as docks are very expensive, underlining the enduring importance of a good port site, albeit inland access also endures as a factor of importance for maritime freight distribution.

Global Commodity Chains and Logistical Strategies

Global production, transportation and distribution require the setting of freight management strategies. As such, logistics concern all the activities required for goods to be made available on markets, including purchase, order processing, inventory management and transportation among the most relevant. The expansion of production in the global realm induced transport systems to adapt to a new environment in freight distribution where the reliable and timely deliveries can be as important as costs. Logistics has consequently taken an increasingly important role in the global economy, supporting a wide array of commodity chains (Hesse and Rodrigue, 2004, 2006). This is the setting in which maritime transportation is increasingly embedded. At the core of this relationship, Global Commodity Chains (GCC) can be considered as functionally integrated networks of production, trade and service activities that cover all the stages in a supply chain, from the transformation of raw materials, through intermediate manufacturing stages, to the delivery of a finished good to a market (e.g. Gereffi, 1999). The development of global transportation and telecommunication networks, information technologies, the liberalization of trade and multinational corporations are all factors that have substantially impacted GCC (Dicken, 2003).

In such a new environment, the precepts of international freight transportation are being re-defined, both for bulk and for break-bulk cargo. The former comprises homogeneous materials without packaging (ores, coal, grain, raw sugar, cement, crude oil and oil products, etc.) usually for a single consignee and destination, while the latter, often known as general cargo, consists of an almost infinite variety of freight, usually in small consignments for numerous consignees and
packaged in a variety of bags, bales, boxes, crates and drums of diverse shape and size. However, containers account for the majority of the break-bulk cargo being carried.

2. Bulk Maritime Freight

Characteristics

The marine industry is an essential link in international trade, with ocean-going vessels representing the most efficient, and often the only method of transporting large volumes of basic commodities and finished products (Gardiner, 1992). In 2005, approximately 2.9 billion tons of drybulk cargo was transported by sea, comprising more than one-third of all international seaborne trade. Bulk freight represents the “traditional” segment of maritime freight distribution with a wide variety of physical characteristics of the cargoes. Each has specific requirements with respect to stowage in the ship, methods of transshipment, and inland transport (Table 1).

Geographically, bulk cargo shows a remarkable stability, particularly in terms of its origins. The extraction and shipment of natural resources, such as minerals and oil, is bound to the geological setting, require massive capital investments and takes place over decades. The maritime traffic associated with these activities is thus highly consistent and varies according to cyclic demand patterns. The same applies for agricultural commodities since agricultural regions are long standing entities with a reasonably consistent output. What is changing more rapidly concerns the destinations of bulk freight as they reflect changes in economic development and the setting of new markets and industrial regions. A remarkable shift thus involved growing demands from the industrializing countries of Pacific Asia and the related changes in the volume of bulk shipping routes.

<table>
<thead>
<tr>
<th>Commodity type</th>
<th>Examples</th>
<th>Maritime Transshipment</th>
<th>Inland distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A) Normal pressure and temperature</td>
<td>Crude oil, most oil products, wine, slurried coal</td>
<td>Pump/pipe</td>
<td>Pipeline</td>
</tr>
<tr>
<td>B) Other pressure and temperature</td>
<td>Liquefied gases (LNG), heavy oils, latex, bitumen, vegetable oils</td>
<td>Pumps, temperature controlled pipelines</td>
<td>Temperature controlled pipelines</td>
</tr>
<tr>
<td>Dry Bulk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A) Flowing</td>
<td>Grain, sugar, powders (alumina, cement)</td>
<td>Pneumatic / suction, conveyor, grabs</td>
<td>Pipes, conveyor, barge, rail wagon, lorry</td>
</tr>
<tr>
<td>B) Irregular</td>
<td>Coal, iron ores, non-ferrous ores, phosphate rock</td>
<td>Grab, conveyor</td>
<td>Convoyer, barge, rail wagon, lorry</td>
</tr>
<tr>
<td>Neo Bulk</td>
<td>Forest products, steel products, baled scrap</td>
<td>Lift-on/lift-off, roll-on/roll-off</td>
<td>Barge, rail wagon, lorry</td>
</tr>
<tr>
<td>Wheeled Units</td>
<td>Cars, lories, rail wagons</td>
<td>Roll-on/roll-off</td>
<td>Rail wagon, lorry</td>
</tr>
<tr>
<td>Refrigerated/chilled cargo</td>
<td>Meat, fruit, dairy produce</td>
<td>Lift-on/lift-off</td>
<td>Rail wagon, lorry</td>
</tr>
</tbody>
</table>

Table 1 Types of Maritime Cargo


Drybulk cargo is shipped in large quantities and can be easily stowed in a single hold with little risk of cargo damage. It is generally categorized as either major bulk or minor bulk. Major bulk cargo constitutes the vast majority of drybulk cargo by weight, and includes, among other things, iron ore, coal and grain. Minor bulk cargo includes products such as agricultural products,
mineral cargoes (including metal concentrates), cement, forest products and steel products and represents the balance of the drybulk industry. In terms of seaborne trade volumes (and the shipping ton-miles generated), the dominant influence is that of the major bulk trades.

The cargo type is reflected in the associated port activity. For the higher unit value containerized break-bulk cargo, a port is usually the gateway through which the cargo passes to the hinterland, while for the bulk cargo it acts as a terminal - the cargo is stored and often processed before onward movement. In the case of many bulk cargo, the port site in often an industrial site linked with the transformation and processing of those commodities. While for a break-bulk flows can be bi-directional (inward and outward), bulk flows are dominantly directional (inward or outward). Bulk cargo is thus imported and processed with the output commonly belonging to a different transport chain that cannot be serviced by the original maritime equipment. Even if the unit and possibly the total value of bulk cargoes may not compare with those of general cargo, the sheer volumes involved give them a special significance in transport systems (Figure 1).

Oil, iron ore, grain and coal accounted for the great majority of ton-miles shipped, about 70% in 2005. Containers and other goods composed the remaining 30%. While the share of containerized traffic has increased significantly, bulk still dominates maritime shipping. It may be argued that raw materials play only a small part in influencing industrial location in general. Nevertheless, there are a number of basic heavy industries - mineral and chemical refining most obviously - where the volume of bulk materials does have a profound impact on the location of processing industries and also on shipping markets, patterns of trade and port activity.

*Transport of Bulk Cargo*

Much of the conventional port industry is a consequence of servicing commodities moving in bulk. For the maritime cargo to be moved specific conditions have to be satisfied (Stopford, 1997):

- **Transportability.** The commodity must have physical characteristics that allow it to be handled and moved in bulk. Liquids such as oil require entirely different, and non-convertible, equipment than solids. Technical improvements have recently permitted the
potential to move natural gas in large quantities through the use of LNG carriers, but it still remains an expensive and technically challenging endeavor.

- **Costs.** The demand and the price for the commodity must be such that the cost of specialized ships and handling equipment is justified. The smallest practicable consignment size will effectively be that of the smallest bulk carrier available. A figure of 1,000 tons has been suggested as a minimum threshold for bulk handling and this has not changed greatly in recent years.

- **Compatibility.** The bulk-shipping operation must be adapted to the overall transport system, so as there is the possibility to move commodities along multimodal transport chains. In many cases, this requires specialized terminals.

- **Load size.** The individual consignment size must be geared to the stocks that can be held at either end of the transport link. This is related to the actual demand at the consuming end, to the storage space available at each end and to the frequency of shipment.

The availability of storage space is an important determinant of the efficiency and productivity of any port since there is an almost inevitable mismatch between the rate of cargo transshipment and the rate at which it enters and leaves the port on the landward side (Takel, 1981). Storage space acts as the essential buffer to balance the flows on the sea and land sides. This is important for general cargoes, but it becomes critical for large volumes of bulk cargo. The amount of space for storage is a function of the density of the commodity where it must allow for access and handling equipment such as stackers, cranes, conveyors and reclaimers. Additional storage space will be needed where materials are sorted by grade or type (e.g. coals, ores and crude oils) and possibly to accommodate changes consequent upon conditions (e.g. wet and dry ores or coal). A regular flow of bulk raw materials is essential for any industrial process. Storage is vital in reducing the effects of flow variations but storage replenishment for a given tonnage can be either by frequent small shipments or by less frequent large shipments. This clearly involves the question of vessel size and choice is influenced by the interplay between economies of scale, consignment size and the physical constraints provided by the routes, ports and handling equipment (Stopford, 1997).

Shipping is less limited by size constraints than other modes and is able to capitalize on what has been called the “cube law”; for a doubling of a ships' dimensions the carrying capacity is cubed. Also, the design, construction and operating costs (crew, fuel) do not increase in proportion with size. A 300,000 ton tanker is able to operate with a crew no larger than that needed for a significantly smaller vessel, although there will be variations depending on national flag regulations, level of automation and company organization (e.g. the amount of emphasis on shipboard maintenance). The same rationale applies for containerships where increasing sizes do not require additional labor and in many cases newer containerships have actually a smaller crew. There is thus a strong rationale in maritime shipping to achieve economies of scale since they are linked with lower operating costs, particularly for bulk carriers, containerships and tankers.

Many bulk trades are effectively one-way traffic with return voyages in ballast. However, while consignments of such size may be available from oil and ore producers and acceptable at the processing plant, this would not be the case for all bulk trades. Also, there is no financial advantage in using large vessels if the loading and unloading rate is slow and the vessel is kept unduly long in port. The ultimate constraint on vessel size remains the physical characteristics of the port (channel depths, turning circles, lock gate dimensions, and berth lengths) and the routes along which ships operate, particularly strategic passages. This has lead to well known capacity standards such as Panamax\textsuperscript{1}, and Suezmax\textsuperscript{2}. A VLCC\textsuperscript{3} of 300,000 deadweight tons can transit the

\textsuperscript{1} The largest vessel that can transit the Panama Canal (draught of 12 meters), a bulk carrier of about 65,000 deadweight tons.

\textsuperscript{2} A VLCC of 300,000 deadweight tons can transit the Panama Canal. However, the draft of 12 meters limits its use in many ports.

\textsuperscript{3} Very Large Crude Carrier.
Strait of Malacca but any larger vessel would have to make a much longer voyage by way of the deeper Lombok Strait. These standards have for long shaped global bulk trades and more recently containerized maritime shipping.

Seasonal demand fluctuations influence many of the bulk trades. Steam coal is linked to the energy markets and in general encounters upswings towards the end of the year in anticipation of the forthcoming winter period (in the northern hemisphere) as power supply companies try to increase their stocks, or during hot summer periods when increased electricity demand is required for air conditioning and refrigeration purposes. Grain production is highly seasonal and driven by the harvest cycle of the northern and southern hemispheres. However, with four nations and the European Union representing the largest grain producers (the United States, Canada and the European Union in the northern hemisphere and Argentina and Australia in the southern hemisphere), harvests and crops reach seaborne markets throughout the year. It becomes a matter of fleet reassignment to follow the seasonality.

*Petroleum Trade*

Petroleum transportation concerns a tightly integrated distribution system that maintains a continuous flow from the oil fields to the final consumption, most of it concerning fuel for transportation. There is limited storage taking place outside the maintenance of strategic reserves. The volume of international oil trade increased as a result of world economic growth and additional demands in energy. Although developed countries such as the United States Western Europe and Japan account for about 75% of global crude oil imports, the largest growth in demand is mainly attributed to China and India. As of 2004, China became the world’s second largest oil importer behind the United States. International oil trade is necessary to compensate the spatial imbalances between supply and demand. Unlike most other countries, which either consume almost their entire production (United States and China) or have privileged partners (Russia and Western Europe), a major portion of OPEC’s oil is traded on international markets.

Each year, about 2.4 billion tons of petroleum are shipped by maritime transportation, which is roughly 62% of all the petroleum produced. The remaining 38% uses pipelines, trains or trucks over shorter distances. Most of the petroleum follows a set of maritime routes between producers and consumers. More than 100 million tons of oil is shipped each day by tankers, about half of which is loaded in the Middle East and then shipped to Japan, the United States and Europe. Tankers bound for Japan use the Strait of Malacca while tankers bound for Europe and the United States use either the Suez Canal or the Cape of Good Hope, pending the tanker’s size and its specific destination.

Different tanker sizes are used for different routes, namely because of distance and port access constraints. There is thus a specialization of maritime oil transportation in terms of ship size according to the markets being serviced. VLCCs are mainly used from the Middle East over long distances (Western Europe, United States and Pacific Asia). “Suezmax” tankers are mainly used for long to medium hauls between West Africa and Western Europe and the United States, while “Aframax” tankers are used for short to medium hauls such as between Latin America and the United States. Transport costs have a significant impact on market selection. For instance, three quarters of American oil imports are coming from the Atlantic Basin (including Western Africa) with journeys of less than 20 days. Venezuelan oil takes about 8 days to reach the United States

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2 Draught of 16 m which can accommodate a loaded tanker of about 200,000 deadweight tons.
3 Very Large Crude Carrier.
4 Between 125,000 and 180,000 deadweight tons.
5 Approximately 80,000 deadweight tons.
while Saudi oil takes 6 weeks. The great majority of Asian oil imports are coming from the Middle East, a 3 week journey. In addition, due to environmental and security considerations, single-hulled tankers are gradually phased out to be replaced by double-hulled tankers (Rodrigue, 2004).

**Coal trade**

Coal is an abundant commodity which is mined in more than 50 countries with no world dependence in any one region. Coking coal is used to produce coke to feed blast furnaces in the production of steel. An increase in seaborne transportation of coking coal has been primarily driven by an increase in steel production. The increase in import activity has occurred in a number of regions. Currently, Asia and Western Europe are major importers of coking coal. Australia and Indonesia provide a significant amount of coking coal to Asia, while South Africa and the United States are major sources for Western Europe. Steam coal is primarily used for power generation. A number of developing countries have decided to capitalize on the recent dramatic increase in oil and gas prices to build new power plants that utilize coal. This has resulted in significant growth in the steam coal trade. The most dramatic growth has occurred in China and Indonesia, both of which have increased their export capacity in the intra-Asian market (World Coal Institute, 2005).

Coal is traded all over the world, with coal shipped long distances by sea to reach markets. Overall international trade in coal reached 755 Mt in 2004 (compared with 383 Mt in 1994). While this is a significant amount of coal it still only accounts for about 16% of total coal consumed. Transportation costs account for a large share of the total delivered price of coal, and as a result international trade in steam coal is effectively divided into two regional markets; the Atlantic and the Pacific. The Pacific market currently accounts for about 50% of world steam coal trade. Australia is the world’s largest coal exporter, exporting over 218 Mt of hard coal in 2004, out of its total production of 285 Mt. Australia is also the largest supplier of coking coal, accounting for 52% of world exports (World Coal Institute, 2005). The USA and Canada are significant exporters and China is emerging as an important supplier. Coking coal is more expensive than steam coal, which means that Australia is able to afford the high freight rates involved in exporting coking coal worldwide.

**Grain trade**

World grain shipments, which reached 250 million tons in 2004, were almost equally split between wheat and coarse grains such as maize, barley, soybeans, sorghum, oats and rye. Grains include wheat, coarse grains (corn, barley, oats, rye and sorghum) and oil seeds extracted from different crops such as soybeans and cottonseeds. In general, wheat is used for human consumption, while coarse grains are used as feed for livestock. Oil seeds are used to manufacture vegetable oil for human consumption or for industrial use, while their protein-rich residue is used as a raw material in animal feed. Total grain production is dominated by the United States. Argentina is the second largest producer followed by Canada and Australia. In terms of imports, the Asia/Pacific region (excluding Japan) ranks first, followed by Latin America, Africa and the Middle East. The principal vessel classes used in the grain trade are Panamax and Handymax (vessels of 30-60,000 dwt).

The grain market is volatile and highly dependent upon weather patterns and yearly harvest changes. This in turn influences the price of grain and indeed freight rates. The ongoing growth of the global population let foresee a continuing growth of the maritime grain trade, particularly imports from newly industrializing countries, many of which are expected to see a net negative balance in grain production.
3. Containerized Maritime Freight

The Containerization of Maritime Transportation

The maritime industry has been transformed by more than 50 years of containerization since the first containerized maritime shipment set sail from Port Newark, New Jersey in 1956. It does not come as a surprise that maritime transportation was the first mode to pursue containerization since it is the most constrained by loading and unloading operations. Containerization permits the mechanized handling of cargoes of diverse types and dimensions that are placed into boxes of standard size. Thus, non-standard traffic that would have required significant and labor intensive transshipment activities becomes standardized with time consuming and costly stevedoring reduced. Instead of taking days to be loaded or unloaded, cargo can now be handled in a much shorter time period as a modern container crane can accommodate about two movements per minute. The most common container is 40 foot in length, the equivalent of two TEUs. Separate transport systems are becoming integrated by intermodal transportation, where each mode tends to be used in the most productive manner. Thus, the line-haul economies of maritime shipping can be combined with the hinterland access provided by rail and trucking. The entire transport sequence is now seen as a whole, rather than as a series of stages, which is changing the role and function of freight forwarders, transport companies, terminal operators and third party-logistics providers.

Containerization has been brought about in part by technology and has substantially impacted maritime design with the creation of the containership. While the first containerships were converted cargo vessels, by the late 1960s the containerized market has grown enough to justify the creation of ships entirely designed for such a purpose. Since that time, the construction of containerships has followed incremental improvements in design with economies of scale being the main rationale (Table 2); the larger the ship, the cheaper the transport costs per TEU (Cullinane and Khanna, 2000). By the late 1980s, the limitations of the Panama Canal of about 4,000 TEU were surpassed, creating a new class of “post-panamax” containerships that have a higher capacity but whose draft and transshipment requirements precludes a number of ports (McLellan, 1997). Once this threshold was overcome, the size of containerships entering service quickly increased. In about a decade containership design went from a maximum capacity of 6,700 TEU to 14,500 TEU. Design constraints are now limited by the capacity of port channels to accommodate containership drafts and as well as the availability of cranes large enough to unload them. In addition, they cause additional pressure on inland transport systems to accommodate the large volume of containers they can transship. Speed-wise, a threshold of about 25 knots has been reached as energy consumption would forbid higher operational speeds.

Table 2 Some Major Landmarks in Containerships Construction

<table>
<thead>
<tr>
<th>Year</th>
<th>Name</th>
<th>Capacity (TEU)</th>
<th>Yard</th>
<th>Length (m)</th>
<th>Width (m)</th>
<th>Draft (m)</th>
<th>Speed (knots)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1956</td>
<td>Ideal X</td>
<td>58</td>
<td>US</td>
<td>174.2</td>
<td>23.6</td>
<td>?</td>
<td>18.0</td>
</tr>
<tr>
<td>1968</td>
<td>Elbe Express</td>
<td>730</td>
<td>B&amp;V</td>
<td>171.0</td>
<td>24.5</td>
<td>7.9</td>
<td>20.0</td>
</tr>
<tr>
<td>1981</td>
<td>Frankfurt Express</td>
<td>3,430</td>
<td>HDW</td>
<td>271.0</td>
<td>32.3</td>
<td>11.5</td>
<td>23.0</td>
</tr>
<tr>
<td>1991</td>
<td>Hanover Express</td>
<td>4,407</td>
<td>Samsung</td>
<td>281.6</td>
<td>32.3</td>
<td>13.5</td>
<td>23.0</td>
</tr>
<tr>
<td>1995</td>
<td>APL China</td>
<td>4,832</td>
<td>HDW</td>
<td>262.0</td>
<td>40.0</td>
<td>12.0</td>
<td>24.6</td>
</tr>
</tbody>
</table>

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6 Twenty Foot Equivalent Units; a standard unit of container traffic measurement.
7 A third-party logistics provider is an asset based company that offers, often through contractual agreements, logistics and supply chain management services to its customers.
The access channel depth of many ports is becoming a constraint on the development of larger containerships. Beyond 45 feet (14 meters) the availability of port sites is restrained, imposing limitations on the port calls for post-panamax containerships. One possibility, like in the airline industry, is the emergence of a limited number of mega-ports linked by high-capacity containerships and serviced by feeder routes. However, a hub-and-spoke network could imply significant additional costs and delays since it would involve additional transshipments and longer routes. Nevertheless, global containerized trade surged in recent years from about 88 million TEU in 1990 to 395 million TEU in 2005. As such, about 70% of the general cargo transported by maritime transportation was containerized.

**Containerized Maritime Terminals**

From a transshipment perspective, the application of containerization has a very strong rationale since the costs, time and reliability of freight distribution are significantly improved. However, due to its physical and logistical characteristics, containerization has placed new demands on port terminals. Most major ports have been transformed to become container ports with the construction of new container terminals, often away from the initial port site. Ports unable to adapt to containerization have mostly declined. In other cases, often because of the insurmountable constraints of the existing port site or because of a surging new demand (such as in Pacific Asia), entire new facilities have been built. Several of the world’s largest container ports simply did not exist 20 years ago. Ports are facing a growing level of sophistication brought by technical and logistical changes. From simple facilities offering wharves and berths to accommodate ships, terminal facilities have emerged where a complete range of maritime (berthing, mooring, transshipment) and inland services (stacking / warehousing, customs, inland distribution) are provided. Containerized maritime terminals are the facilities in which these range of services are the most developed and extensive. However, providing this essential range of services is not without constraints, mainly concerning:

- **Space consumption.** Container terminals are extensive consumers of space, particularly for the temporary storage of containers waiting to be loaded on ships or picked up for inland distribution. Although containerships spend significantly less port time, the growth of containerized trade and their larger capacity have placed pressures on existing terminals to expand laterally. Ports where lateral expansion was possible have thus been able to accommodate the growth of containerized maritime shipping.

- **Depth.** As the size of containerships increased, so did the port depth requirements to handle them. Post-panamax containerships impose berth depths of at least 14 meters and the new generation of containerships having capacities above 8,000 TEU demands depths in the range of 15-16 meters (at least 50 feet). For several container ports, meeting those requirements has become prohibitive since it would involve the construction of new berth facilities and extensive dredging (often not possible due to environmental restrictions). Doing so also takes place at the risk of attracting enough additional traffic to justify those investments.

- **Investment in infrastructure.** In the past, port operations involved simple cranes and labor intensive transshipment activities. The situation has now become very capital.
intensive while labor requirements have been reduced. Modern containerized operations require a limited amount of labor, but the skill level of this labor is much higher. Each new generation of containerships, in addition to their draft, require larger and more efficient cranes. The level of capital investment becomes very demanding. This takes place in the context of growing hinterland competition where ports are less secure about the stability of their customer base.

- **Inland connections.** Traditionally inland access was of lesser importance because most of the warehousing was directly adjacent to port terminals. These facilities stored the freight related to maritime shipping and this freight moved inland as orders were being filled. The situation substantially changed with containerization. Containers are bound directly to their destinations with only temporary stacking at port terminals. The importance has shifted to the capacity of inland transport systems to handle high container throughputs related to port terminals. For large ports, providing inland distribution capacities has become one of the most serious challenges with initiative such as on-dock rail access and transshipments to/from barges.

Figure 2 reveals an emerging geography of containerized maritime terminals. Aside from the conventional port clusters in Europe and North America many corresponding to older ports partly or wholly converted to containerization, new regions and new port clusters have emerged, mainly in Pacific Asia. The most substantial growth took place along the Tokyo – Singapore corridor, where economies have followed the export-oriented model, producing consumption goods highly prone to the use of containerization and bound for the global market.
Figure 2: The World's 50 Largest Container Ports, 2004

Traffic 2004 (TEU)
- Less than 2 million
- 2 to 4 million
- 4 to 7 million
- 7 to 10 million
- More than 10 million

[Map showing the world's 50 largest container ports with different symbols representing traffic volumes.]
Global Port Operators

A significant trend in container port operations has been the increase of the role of private operators (Olivier and Slack, 2006; Slack and Fremont, 2005). In an era characterized by lower levels of direct public involvement in the management of transport terminals, specialized port operators have emerged. Concession agreements in which subdiary companies (commonly joint ventures) are established have been the major tool for port operators to take control of terminals. A concession agreement is a long-term lease of port facilities involving the requirement that the concessionaire undertakes capital investments to build, expand, or maintain the cargo-handling facilities, equipment, and infrastructure. This enables port authorities to secure additional revenue and minimize risk by leasing some of their facilities. Elsewhere, a simple minority stake was acquired by shipping lines, enough to secure handling capacity for their vessels.

A total of 24 major port holdings where in operation in 2005, handling about 267 million TEUs. Four in particular have substantial global assets of about 30-40 dedicated port terminals each; APM Terminals (controlled by the Danish maritime shipper Maersk), Dubai Ports World (DPW), Hutchison Port Holdings (Hong Kong), and the Port of Singapore Authority (PSA). Jointly, they controlled 143 dedicated maritime container terminals in 2007. Several other port holdings exist, owned by specialized private companies (such as SSA for North America or Eurogate for Europe) or by ocean carriers (Hanjin and Evergreen have notable assets), but their focus is mostly regional. A concentration of ownership among four major port holdings is taking place, such as in 2006 when DPW acquired the terminal assets of P&O (Peninsular & Oriental Ports) further consolidating its global holdings. However, DPW was constrained to renege the American assets of this transaction (Baltimore, Miami, New Orleans, New York and Philadelphia) to the holding AIG due to a political controversy; a Middle Eastern holding operating major American port terminals was perceived negatively in the post 9-11 setting. Port holdings are thus the outcome of horizontal integration through expansion and mergers with the process leading to a high level of concentration of the global containerized throughput. For instance, HPH accounted for 26% of world container port capacity with a container throughput of around 51.8 million TEUs in 2005. PSA ranked second, at 19%, handling 41.2 million TEUs for the same year. The main rationale behind the emergence of large port holdings includes:

- **Financial assets.** Port holdings have the financial means to invest in infrastructures as they have a wide variety of assets and the capacity to borrow large quantities of capital. They can use the profits generated by their efficient terminals to invest and subsidize the development of new ones, thus expanding their asset base and their operating revenues. Most are listed on equity markets, giving the opportunity to access global capital, which realized in the last decade that the freight transport sector was a good source of returns driven by the fundamentals of a growth in international shipments. This financial advantage cannot be matched by port authorities even those heavily subsidized by public funds.

- **Managerial expertise.** Port holdings excel in establishing procedures to handle complex tasks such the loading and unloading sequence of containerships and all the intricacies of port operations. Many have accumulated substantial experience in the management of containerized operations in a wide array of settings. Being private entities, they tend to have better customer service and have much flexibility to meet the needs of their clients. This also includes the use of well developed information systems networks and the capacity to quickly comply with legal procedures related to customs, clearance and security.

- **Gateway access.** From a geographical standpoint, most port holdings follow a strategy aimed at establishing privileged positions to access hinterlands. Doing so they secure a
market share and can guarantee a level of port and often inland transport service to their customers. It can also be seen as a port competition strategy where a “stronghold” is established, limiting the presence of other competitors. Gateway access thus provides a more stable flow of containerized shipments. The acquisition of a new port terminal is often accompanied by the development of related inland logistics activities by companies related to the port holding.

- **Leverage.** A port holding is able to negotiate with maritime shippers and inland freight transport companies favorable conditions, namely rates, access and level of service. Some are subsidiaries of global maritime shipping lines (such as the A.P. Moller group controlled by the shipper Maesrk) while others are directly controlled by them (such as Hanjin or Evergreen) so they can offer a complete logistical solution to international freight transportation. The “footloose” character of maritime shipping lines has for long been recognized (Slack, 1994), with a balance of power more in their favor than of the port authorities they negotiate with.

- **Traffic capture.** Because of their privileged relationships with maritime shipping lines, port holdings are able to capture and maintain traffic for their terminals. The decision to invest is often related to the knowledge that the terminal will handle a relatively secure number of port calls. Consequently, a level of traffic and revenue can be secured more effectively.

- **Global perspective.** Port holdings have a comprehensive view of the state of the industry and are able to interpret political and price signals to their advantage. They are thus in position to influence the direction of the industry and anticipate developments and opportunities. Under such circumstances they can allocate new investments (or divest) to take advantages of new growth opportunities and new markets.

The main strategy of port holdings consists in the establishment of a network of port terminals capturing the export-oriented traffic of Asia, offshore transhipments opportunities for long distance trade and improving hinterland access for import markets, particularly at the major continental gateways of Western Europe and North America (Figure 3). The issue of port competition has been rendered more complex by this emerging ownership structure. In some ports, the holding controls the entire facility and is thus the port’s sole client while other holdings and shipping lines may face a more difficult access in terms of berthing and efficient transshipment. The approach in port competition, notably from other port holdings, thus becomes a strategy of establishing a handhold on a nearby facility that shares a similar hinterland. For instance, A.P. Moller went to the port of Tanjung Pelepas near Singapore, because the later is controlled by PSA. For other ports, particularly large ones, intense competition is the trend as often more than two holdings are present, each owning their own terminals within the port complex (e.g. Rotterdam, Antwerp, Laem Chabang, Hong Kong and New York). This strategy is likely to make shipping lines less “footloose” since they now have vested long term interests at specific port terminals and selling those interests is much more difficult than negotiating a short term service contract with a port authority.


**Offshore Terminals**

In a conventional pendulum container service, a maritime range such as the American East Coast could involve several port calls. Pendulum services involve a set of sequential port calls along a maritime range, commonly including a transoceanic service from ports in another range and structured as a continuous loop (Slack, 1998). They are almost exclusively used for container transportation with the purpose of servicing a market by balancing the number of port calls and the frequency of services. If the volume is not sufficient, this may impose additional costs for maritime companies that are facing the dilemma between market coverage and operational efficiency. By using an offshore hub terminal in conjunction with short sea shipping services, it is possible to reduce the number of port calls and increase the throughput of the port calls left (Baird, 2006). Offshore terminals can thus become effective competitive tools since the frequency and possibly the timeliness of services can be improved. An outcome has been the growing share of transshipments in regard to the totality of containerized traffic, from around 11% in 1980 to about 28% in 2005 (Drewry Shipping Consultants, 2006). The world’s leading offshore hub is the port of Singapore, where about 91% of its 19.1 million TEU volume was transshipped in 2004. This is mainly attributable to its strategic location at the outlet of the Strait of Malacca, the world’s most heavily used shipping route that transits about 30% of the world trade. Other major offshore hubs are Freeport (Bahamas), Salalah (Oman), Tanjung Pelepas (Malaysia) or Gioia Tauri (Italy), Algeciras (Spain), Marsaxlokk (Malta), Taranto (Italy) and Cagliari (Italy). These hubs particularly owe their emergence to the following factors:

- **Location.** Offshore hubs have emerged on island locations or on locations without a significant local hinterland to fulfill a role of intermediacy within global maritime networks (Fleming and Hayuth, 1994). They are close to points of convergence of maritime shipping routes where traffic bound to different routes can be transloaded. Offshore hubs tend to be located nearby major bottlenecks in global maritime networks (Strait of Malacca, Mediterranean or the Caribbean) as they take advantage of the convergence effect.

- **Depth.** Offshore terminals tend to have greater depth since they were built recently in view to accommodate modern containership drafts, placing them at a technical advantage over many older ports. Their selection often involves a long term consideration of growing containership drafts and the future capacity, in terms of transshipment and warehousing, of the hub to accommodate such growth.

- **Land availability.** The sites of offshore terminals tend to be less crowded and outside the traditional coastal areas that have see a large accumulation of economic activities. They often have land for future expansion, which is a positive factor to help securing existing and future traffic.

- **Labor costs.** Labor costs tend to be lower, since offshore terminals are located at the periphery and they tend to have less labor regulations (e.g. unions), particularly if it concerns a new terminal facility.

- **Hinterland access.** Limited inland investments are required since most of the cargo is transshipped from ship to ship with temporary storage on the port facilities. The footprint offshore terminals have on the local or regional transport system is thus limited. In addition, the port operator does not have to wait for local/regional transport agencies to provide better accessibility to the terminal, which is often a source of conflict between the port and the city/region.

- **Ownership.** Terminals are owned, in whole or in part, by port holdings or carriers which are efficiently using these facilities and are free to decide future developments or reconfigurations. Offshore terminals are avoiding a legacy of governance structure controlled by port authorities. They thus tend to be responsive and adaptable to market changes.
In an initial phase offshore terminals solely focus on accommodating transshipment flows and many have a transshipment share exceeding 80% of their container volume. As the transshipment business remains highly volatile, offshore hubs can eventually develop services that add value to the cargo instead of simply moving containers between vessels. This strategy could trigger the creation of logistics zones within or in the vicinity of the port area, in many cases implemented as Free Trade Zone.

4. Logistics and the Maritime / Land Interface

Maritime Logistics

Although maritime companies have always managed their fleet from an operational standpoint, such as scheduling, ports serviced and cargo handling, containerization truly permitted the convergence of maritime shipping and logistics. As such, maritime shipping lines are more related to the requirements of their customers, in terms of price, timing, frequency and level of service. Maritime logistics is thus the convergence of several integration processes including intermodal, economic and organizational in order to add value along the maritime transport chain (Panayides, 2006). Among the many strategies behind freight integration, the provision of “door to door” services is privileged, which favors a higher application level of maritime logistics.

Thus, new forms of cooperation are emerging in the maritime industry, among shipping lines, but also with actors involved in other modes and other transport services. This cooperation can take many forms, including mergers and acquisitions, joint ventures, contractual agreements and minority stakes. In such a setting, shipping lines each adopt strategies that fit their goals and the management of their assets. Maritime logistics confers a level of flexibility such as how maritime companies allocate their containerships, manage their containers, have access to specific port terminals and inland transport systems and perform a range of value-added activities (Notteboom and Merckx, 2006). Maritime logistics is thus becoming closely integrated with inland logistics.

New Services and Networks

In an environment of substantial growth in international trade, a small group of very large shipping lines has emerged, along with a concentration of the traffic. While the top 20 carriers controlled 26% of the world slot capacity in 1980, this figure moved to 42% in 1992 and to 58% in 2003. These carriers are also integrated horizontally, mainly through agreements such as liner conferences, operating agreements (vessel sharing, slot chartering, consortia and strategic alliances) and mergers and acquisitions. Mergers and alliances have been particularly prevalent in the maritime industry. The main rationale in mergers and the formation of alliances is rather simple; increase income and reduce costs. Each member is able to provide exiting assets that would be complementary to those in the alliance. Of particular relevance is a geographical complementarity where respective networks and markets are brought together. As private ventures, they aim to establish and maintain profitable routes in a competitive environment. This involves three major decisions about how such a maritime network takes shape (Notteboom, 2004, 2006):

- **Frequency of service.** Frequency is linked with more timely services since the same port will be called at more often. A weekly call is considered to be the minimum level of service but since a growing share of production is time dependent, there is a pressure from customers to have a higher frequency of service. For a similar total traffic, a trade-off between the frequency and the capacity of service is commonly observed. This trade-off is often mitigated on routes that service significant markets since larger ships can be used with the benefits of economies of scale.
• **Fleet and vessel size.** Due to basic maritime economics, large ships, such as post-panamax containerships, offer significant advantages over long distances. Shipping lines will obviously try to use this advantage, keeping smaller ships for feeder services. In addition, a large enough number of ships must be allocated to insure a good frequency of service. To keep their operations consistent, lines also try to have ships a similar size along their long distance pendulum routes (see below). This is not an easy undertaking since economies of scale force the introduction of ever larger ships which cannot be added all at once due to extensive financial requirements and the capacity of shipbuilders to supply them. So each time a bigger ship is introduced on a regular route, the distribution system must adapt to this change in capacity.

• **Number of port calls.** A route that involves less port calls is likely to have lower average transit times in addition to requiring a lower number of ships. Conversely, too few port calls could involve difficulties for the cargo to reach inland destinations remote from the serviced ports. This implies additional delays and potentially the loss of customers. An appropriate selection of port calls along a maritime facade will help insure access to a vast commercial hinterland.

The emergence of post-panamax containerships has favored the setting of pendulum services since the maritime landbridge of Panama is no longer accessible to this new class of ships. For instance, pendulum services between Asia and Europe have on average 8 to 10 containerships assigned and involve 8 to 12 port calls. Most transatlantic pendulum services have 6 to 8 containerships and involve 6 to 8 port calls (Figure 4). A pendulum service is fairly flexible in terms of the selection of port calls, particularly on maritime ranges that have nearby and competing ports grouped as regional clusters (e.g. North American East coast, Western Europe). This implies that a maritime company may opt to by pass one port to the advantage of another if its efficiency is not satisfactory and if its hinterland access is problematic. The shipping network consequently adapts to reflect changes in market conditions. One such example was the abandonment of round-the-world services by Evergreen in 2002, which were instead replaced by three pendulum services that offer more weekly port calls. The frequency of service of two calls per week was judged insufficient to meet the needs of its customers.
The three main markets serviced by pendulum services are Western Europe (Atlantic and Mediterranean Facades), North America (Atlantic and Pacific Facades) and Pacific Asia (Figure 4). Each is serviced by a series of port calls where containers are transshipped to offshore hubs or

![Map showing pendulum routes serviced by OOCL, 2006.](image)

**Figure 4: Three Major Pendulum Routes Serviced by OOCL, 2006.**

<table>
<thead>
<tr>
<th>Origin</th>
<th>Destination</th>
<th>Transit Time (days)</th>
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</thead>
<tbody>
<tr>
<td>Southampton</td>
<td>New York</td>
<td>8</td>
</tr>
<tr>
<td>New York</td>
<td>Norfolk</td>
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</tr>
<tr>
<td>Port Kelang</td>
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<td>4</td>
</tr>
<tr>
<td>Singapore</td>
<td>Port Kelang</td>
<td>1</td>
</tr>
</tbody>
</table>

**Atlantic Express (ATX)**

**European Union / Mediterranean (EUM)**

**South China Express (SCX)**

- **Note:** Transit time includes port time.
- **Note:** Paths are approximate.
- **Note:** Transit time includes port time.

<table>
<thead>
<tr>
<th>Origin</th>
<th>Destination</th>
<th>Transit Time (days)</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
<td>Kaohsiung</td>
<td>Shekou</td>
<td>1</td>
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<tr>
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<td>Laem Chabang</td>
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<td>4</td>
</tr>
<tr>
<td>Oakland</td>
<td>Tokyo</td>
<td>9</td>
</tr>
</tbody>
</table>

**Source:** OOCL Web Site
to hinterlands, depending on the function of the port. The itinerary of a pendulum service is thus carefully selected to insure distribution strategies that reflect the global and regional framework of trade. For instance, in a pendulum service, most of the traffic is bound to the other end of the pendulum. This is particularly the case for the United States where cabotage regulations (Jones Act) would forbid a foreign owned shipping lines to carry traffic between American ports. In addition, large high capacity ships can be used for pendulum services (such as across the Pacific) since they are not required to transit through the Panama Canal and that the Suez Canal can accommodate the current generation of very large containerships (up to 16 meters / 12,000 TEU).

Because of the capacity limits of the Panama Canal, many shipping companies have changed the configuration of their routes. This became increasingly apparent as a growing share of the global containership fleet was at a size beyond its capacity. The increasing usage of those ships along the Pacific Asia / Suez canal / Mediterranean route as well as the development of the North American rail landbrige have created a substantial competition to the canal as an intermediate location in global maritime shipping. In addition, estimates indicate that the Panama Canal may reach capacity by 2009-12. There are thus plans to increase its capacity and accommodate larger containerships, a decision which was finally reached in 2006 by the Panamanian government. The expansion project involves building a new set of locks on both the Atlantic and Pacific sides of the canal to support a depth of 60 feet, a width of 190 feet and a length of 1,400 feet, which would accommodate ships up to 14,000 TEU. The dredging of access channels as well as the widening of several sections of the existing canal will also be required. This would allow Aframax and Suezmax vessels to pass through the canal, thus permitting new opportunities for container services such as the re-emergence of round-the-world services.

**Containerized Flows and their Global Imbalances**

The production and distribution environment in which maritime transportation evolves is also characterized by distortions in international trade patterns caused by globalization and the relocation / development of new manufacturing activities in emerging industrial regions. The Pacific Asian maritime range has been the major recipient of this industrial accumulation, mainly due to the ability to gain from comparative advantages. Container flows are quite representative of global trade imbalances, which have become more acute in recent years (Figure 5).

![Figure 5 Containerized Cargo Flows along Major Trade Routes, 2005 (in million TEU)](image-url)
While American containerized imports from Asia increased by 148% between 2000 and 2005, opposite flows have grown to a much lesser extent (30%); there are 3 times as many containers moving from Asia to the United States than there are in the opposite direction. An imbalance between Asia and Europe is also observed, but to a lesser degree. Thus, production and trade imbalances in the global economy are clearly reflected in imbalances in physical flows and transport rates. On the Pacific, it costs about twice as much per TEU for westbound flows than for eastbound flows, making freight planning a complex task for container shipping companies. In addition, there has been a notable growth in the movement of empty containers.

Empty containers (“empties”) account for about 21% of the volume of global port handling (Boile et al., 2006). They pose a logistical challenge to both the maritime and inland segment of freight distribution, an issue being underlined by the fact that at any given time about 2.5 million TEU of containers are being stored empty, waiting to be used. The maritime industry has been hard pressed to address these imbalances but little can be done since they reflect macro-economic issues outside their control. Among the strategies been considered is the immediate repositioning of containers that have just been emptied to nearby export-based activities. The use of foldable containers is also a possibility since it reduces the repositioning costs (Konings and Remmelt, 2001). However, no immediate solution is possible since the core of the issue remains macro economic imbalances.

The Convergence of Inland and Maritime Logistics

There is a clear trend involving the growing level of integration between maritime transport and inland freight transport systems (Heaver, 2005; Robinson, 2002; Panayides, 2006). 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 (Notteboom and Rodrigue, 2005). 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 corridor8, are implemented in addition to trans-continental strategies such as the existing North American landbridge and the planned

8 The Alameda Corridor is a 20-mile rail freight expressway linking the port cluster of Long Beach and Los Angeles to the transcontinental rail terminals near downtown Los Angeles. It was built to provide better rail access to the port cluster, which is the most important in North America in terms of the volume and value of its containerized traffic. The Alameda Corridor consists in a series of bridges, underpasses, overpasses, and street improvements that separate rail freight circulation from local road circulation.
Northern East-West Freight Corridor spanning across the trans-Siberian to the port of Narvik in Norway with an oceanic leg across the Atlantic.

5. Conclusion: Ports as Elements of Global Logistical Chains

The development of bulk and containerized maritime transportation has been strongly influenced by technology (Pinder and Slack, 2004). Economies of scale have been achieved through the construction of larger ships and this in turn has affected the optimum shipment size, vessel routings and port selection. While this process is mostly over for bulk transport, it continues unabated for containerized shipping with the introduction of larger ships. Port selection is especially relevant because of the strong link between ports and industrial activity, but particularly between the port and its hinterland. However, technology and vessel design are by no means the only factors at work to influence the patterns of the world maritime shipping; government policy, commercial buying practices and physical constraints such as water depth in ports also play a key role.

Until recently the individual elements of the transport chain, while functionally related, were operated in a largely disparate way. In the bulk trades, as in maritime transport in general, there is now a realization that the integration of supply chains requires a high level of organizational interdependence. Maritime transportation and inland transportation must increasingly be seen as functionally integrated. In bulk as in containerized trades the reduction of inventory and storage costs by just-in-time (JIT) shipments and door-to-door services are increasing in significance. Freight transportation becomes focused on providing the most extensive services possible within expected cost and reliability parameters. In such a context of flexible maritime networks, such as pendulum services and economies of scale, ports are hard pressed to act as efficient nodes in global logistical chains. Their responses have involved establishing better hinterland connections and in many cases private terminal operators have stepped in to directly manage the facilities. The global port and maritime landscape is thus adapting to new environment reflecting economic, technological and political changes.

6. References


