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The feasibility of mega container vessels

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Abstract

The introduction of the container revolutionised maritime trade and shipping. Since 1956 container vessels have evolved from converted tankers and cargo ships, via full cellular container ships that could navigate the Panama Canal, to post-Panamax vessels with a capacity of approx. 8500 TEU (Twenty foot Equivalent Unit). Even bigger container ships (9600 TEU) are to be delivered soon. However, current technical and physical constraints such as propulsion and port limitations pose restrictions to further growth. Moreover, the diminishing economies of scale in ship costs are offset by the increase of other costs involved (e.g. port fees, terminal handling charges). Nevertheless, empirical research shows that the concept of mega container vessels is appealing and that, if available, most shipping lines will deploy such ships. So, the next generation container ships will probably consist of Suez-max vessels (up to 12,500 TEU) with twin propulsion systems. Albeit feasible from a technical point of view the ultimate 18,000 TEU container ship i.e. Mallaca-max has too many limitations to become popular.

Keywords: Container vessels; Shipping lines; Container revolution.

1. Introduction

With the internationalisation and globalisation of economies shipping has obtained a central role in world trade. Most of the general cargo is transported in containers. The increase in volume of containerised cargo is continuing from the last decades into the beginning of this new century. On most major routes a doubling of volume occurred in less than ten years. The current fleet of container ships with a total capacity of 7 million Twenty foot Equivalent Units (TEU) has also doubled since 1997 (Mainport News, 2004). Moreover, ship size is still increasing. In this paper the (future) development of containerships is examined. From a historical perspective a trend is described towards vessels of 10.000 TEU. Already on the drawing board are Ultra-Large Container Ships (ULCS) up to 12,500 TEU such as Suez-max and even Malacca-max container carriers (18,000 TEU). However, it seems that for these mega container ships new technical and logistical concepts are needed. Via desk research the pros and cons of such vessels were identified. In addition, executives of major container shipping lines in Asia and Europe have been interviewed. Finally, conclusions will be drawn on the feasibility of these mega carriers.

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2. The development of container vessels

2.1 The early years

Modern marine containers are the brainchild of Malcolm McLean, a U.S. truck operator who diversified into shipping in 1955 with the acquisition of Pan Atlantic Steamship Company and Waterman Steamship Company. The dimensions of the first containers were based on the limitations of trailers allowed on the highways at the time in New York State: 35 ft long x 8 ft wide x 8 ft high. McLean converted one of his Pan Atlantic T-2 tankers, Ideal X, into the first vessel that was able to carry containers. By constructing a spar deck over the piping and manifold 58 35-foot container slots, an equivalent of approximately 102 TEU, were created. Using the operating rights of the Pan Atlantic Steamship Company, the Ideal X set sail on April 26, 1956 from Newark (NJ) to Houston (TX), carrying 58 reinforced trailer vans complete with their wheel chassis. Two months later another converted tanker, Maxton, with a capacity of 62 containers (˜109 TEU) joined the Ideal X. These ships came to be known as \`Trailerships´.

Already in 1957 the first vessels to solely carry containers stacked in vertical cells, entered service. This series of six converted C-2 cargo ships each with a capacity of 226 reinforced trailer bodies (˜396 TEU), was equipped with two ship-mounted gantry cranes for (un)loading. The first vessel, Gateway City, departed Port Newark on October 4, 1957. In May, 1966 one of its sister ships, Fairland, started the first transatlantic service with full container vessels.

The second shipping line that was heavily involved in early containerisation was Matson Navigation, a major player in the California – Hawaii trade. In contrast with McLean, adoption of the container concept was based on extensive research. On August 31, 1958 the Hawaiian Merchant, one of their C-3 class freighters with a capacity of 70 24-foot containers (˜84 TEU) on deck, sailed from San Francisco to Hawaii with 20 boxes. Again the size of Matson's containers was determined by road regulations; in California the rule on doubling up on trailers was limited to 24 feet for each trailer. In 1960 the Hawaiian Citizen with a capacity for 436 24-foot containers (˜523 TEU), became their first full container carrier. Matson also paid a lot of attention to the transhipment process. In the 1960's port facilities were improved by installing special gantry cranes for rapid and efficient shore-based handling of containers. Soon, it was no longer necessary to put cranes aboard ship. (Muller, 1995). By 1965 these two pioneering container shipping lines handled 70% of US container transport.

The success of the container lies in efficiently facilitating the flow of goods between the transport subsystems of sea, rail, road and, to a lesser extent, inland waterways. The standardised container is a gateway between different subsystems of transportation. Gateway technology is defined by David and Bunn (1988, p.170) as "a means (a device or convention) for effectuating whatever technical connections between distinct production sub-systems are required in order for them to be utilised in conjunction, within a larger integrated production system." However, the introduction of the maritime container in international trade required new standards. In order to achieve operational exchangeability an ISO-committee on container dimensions was installed in 1961. At that moment road regulation in most States permitted 40 foot length and 8 foot width. Since US-regulation was stricter than the dimensions permitted on European roads the proposal of the Americans (then 8 x 8 x 10/20/40 ft) was accepted in 1962.

One year later, these dimensions were supplemented with, among others, lengths of 30 ft. In 1969, the US delegation proposed a height of 8'6", which was used by North Atlantic Services. Although initially accepted exclusively for the 40 ft container, in 1972 this height was also accepted for 20 and 30 ft containers (Egyedi, 2000).

2.2 The Panamax age

Ships built prior to 1969 were converted from break bulk ships or tankers. They generally had capacity in the 750 to 1000 TEU range, draft of about 9 meters, and commercial speeds of 18 to 21 knots and were often fitted with shipboard cranes to handle containers.

In 1968 the first pure cellular containerships was commissioned; United States Lines' American Lancer, was delivered on May 17, 1968. This vessel of 18,764 GRT had a container capacity of 1,342 TEU. Its service speed amounted 17.4 knots. Cellular container ships were designed to utilize dockside rather than shipboard cranes. Removing the cranes both increased cargo-handling productivity and allowed more containers to be stowed on deck. This began a new generation of larger and faster containerships with capacities in the 1,000 to 2000 TEU-range, often referred to as second generation container ships (Cullinane et al., 1997).

European shipping lines followed suit. Already in the early 1970s a further increase in ship size, with capacity moving into the 1500 to 3000 TEU-range, becomes apparent. The maximum capacity of this third generation type of container vessels was limited by the width of the Panama Canal. The first Panamax container ship with the maximum beam of 32.3 meter was Overseas Containers Ltd (OCL) Liverpool Bay of 2,961 TEU, launched in 1972.

At that time service speeds were already important for break-bulk vessels but gained momentum for containerships. Some ships with huge power plant(s) and multiple screws could achieve speeds up to 28 knots. Renowned for their speed were Selandia and Jutlandia of the Danish East India Company equipped with triple screw (!) and three Diesels engines, delivering a 55,250 kW (75,000 BHP). In 1972/73 Sea-Land took delivery of eight 33-knot containerships capable of carrying 1900 TEU. This speed was realized by installing two steam turbines (88,500 kW/120,000 BHP) and two screws. To date, the speed of these SeaLand ships has not been surpassed by subsequent designs. However, they turned out to be an economic failure when fuel prices went skyward and the vessels were sold to the U.S. military. Nowadays service speed is in the 24-26 knot range.

During the second half of the 1980s, the capacity of Panamax containerships rose to more than 4,000 TEU by stretching its length to Panama Canal limits i.e. 294 meter. The famous "Econoships" designed by U.S. Lines to operate on a round-the-world service and delivered in 1984-1985 were able to carry 4458 TEU. In order to maximize fuel efficiency these vessels were equipped with a small power plant but were too slow for the intended service.

The dimensions of the ultimate (fourth generation) Panamax vessel e.g. Hapag Lloyd’s Antwerp Express class, amount 294.2 meter Length Over All, a beam of 32.3 meter (= 13 rows of containers across deck) and a maximum draft of approx. 13.5 meter. This enables a maximum load of around 4,900 TEU, an increase in transport volume of 50 % as against that of the third generation designs. The number of crewmembers at the same time has been reduced by about 40%.

2.3 The post-Panamax era

Post-Panamax containerships first appeared in 1988 when American President Lines ordered five C-10 class ships of 260.8 meter length and 39.4 meter width with a capacity of 4,300 TEU for use in transpacific service. Amazingly, capacity did not exceed the "Econoships". However, the advantages of such a vessel include lower investment cost i.e. for the same TEU capacity, the shorter post-Panamax ship is 5 percent cheaper to build. Also, the operating expenses are lower because the wider post-Panamax ship requires little or no ballast and thus consumes less fuel. The decision of American President Lines to omit Eastern Seaboards ports from its transpacific service was based on the emergence of double stack container trains. In this way a cost-efficient alternative for the Panama Canal passage was offered

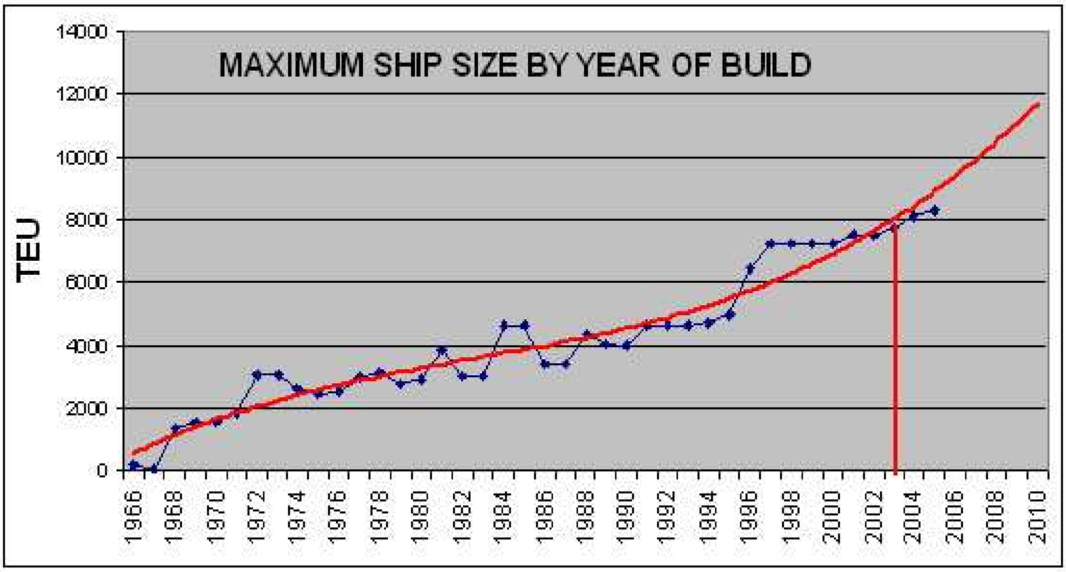
Although the principal advantage of the post-Panamax ship is its virtually unlimited container capacity, the fifth generation type of container ship that was delivered in the early to mid-1990s all had limited LOA's and beams enabling 15 rows of containers across the hatches. A typical container ship of this generation has a capacity ranging from 5,000 to 5,500 TEU. During this period much attention was paid to the efficiency of the transhipment process and several shipping lines (a.o. Nedlloyd, Norasia) introduced innovative open-top (hatchless) container vessels. Albeit this system was not successful for larger vessels it is still used for smaller containerships including barges.

It took until 1996 when the sixth generation containership was commissioned. The A.P. Möller-group became the frontrunner of these developments. The Regina Maersk, a K-class Very-Large Container Ship (VLCS) of Maersk Line set new standards with a carrying capacity of (more than) 6,000 TEU. The dimensions of the vessel are: Length Over All (LOA) 318.2 meters, a beam of 42.8 meters, spanning 17 containers across the deck, and a draft of 14 meters. Launched in 1998 the Sovereign Maersk, was 29 meters longer than Regina Maersk. The 19 'Sovereign' class vessels are able to carry 6,600 TEUs. Six newbuildings that are even longer (5 meter) than the 347 meter long Sovereign Maersk are (to be) delivered in 2003 and 2004. Its 12-cylinder Diesel engine develops 63,000 kW (equivalent to 85,500 BHP) at 100 revolutions per minute, which allows a cruising speed of 25.5 knots. According to the owner, the capacity of the Axel Mearsk and her sister ships is also 6,600 TEU. Rumouors in the industry, however, suggest a capacity of approximately 10,000 TEU.

The Axel Maersk ranks among the largest container vessels in the world. Officially the 8,000 TEU barrier was breached in 2003 by the 323 meter long OOCL Shenzhen with a capacity of 8,063 TEU. At the time of ordering the engine restricted capacity to 7,700 TEU but due to technical innovations it could be increased. At the moment the largest containership in the world is China Shipping Container Line's (CSCL) 8,486 TEU ASIA. Additionally, four sister ships will be joining CSCL's fleet. The dimensions of these vessels: Length Over All 334 meter, beam 42.8 meter and draft 14.5 meter. The air draft of such a vessel is 61.5 meter! A twelve cylinder 68,615 kW (93,120 BHP) Diesel engine with 104 rpm provides a service speed of 25.2 knots. The container vessel took a total of 16 months to complete, 8 months in designing and another 8 months in construction. (Samsung Heavy Industries, press release 2004/07/07)

2.4 Future trends

The graph below shows the actual increase of container ship size until the year 2000. Existing information about newbuildings is also included but already outdated by recent developments. By extrapolating the data a trend is derived.



Source: Lloyd's Register and Ocean Shipping Consultants Ltd, 2000.

Since the mid-1990 the size of container ships has increased rapidly and newbuildings keep getting bigger. As of 1st January 2004 already 30 container ships of above 7,500 TEU are in service and another 126 ships are on order (http://www.brs-paris.com/). Up to around 10,000 TEU vessels will reflect current design parameters and will be powered by a single main Diesel engine, with a power output of 66,500 kW (90,000 BHP) plus, generating a minimum 25-knot service speed. Compared to the design of the CSCL Asia it will take about a year to design such a vessel. Anything beyond that size will have to be twin-engined, particularly, if a 25-knot service speed is to be maintained. For these vessels the Suez Canal imposes the next boundary. The slightly V-shaped bottom of the canal allows common U-hulled Ultra Large Container Ships (ULCV) of 400 meter length, beam of 50 meters (= 20 containers) and draft of 17 meters. Such a Suez-max vessel can carry up to approximately 12,500 TEUs. From a theoretical point of view the size of containerships is constrained by the maximum depth for transiting the Mallaca Straits. This vessel, called Malacca-max, is 400+ meters long, 60 meters wide (= 24 containers) and has a draft of 21 meters. It would be able to carry roughly 18,000 TEUs. (Wijnolst et al, 1999).

3. Barriers to further growth

The development of ever-larger container ships is, however, restricted by technical and physical constraints, logistical implications and economic aspects.

3.1 Technical and-physical constraints

Propulsion

As mentioned before, the currently available Diesel engines do not allow substantial increases in ship size anymore. The largest slow-speed Diesel engines provide propulsive power for a post-Panamax ship of about 8,500 TEU to achieve a service speed of about 25 knots, the industry standard. Beyond this size, larger or two engines have to be installed. It is clear that shipowners prefer the well-proven concept of one engine, one propeller. Recently, two designers and licensors for large slow speed Diesel engines have developed stronger engines. Single screw containerships of 10,000 TEU+ are feasible with these engines. However, the overall length of these engines may cause problems with engine rigidity as well as regarding possible interaction with the hull, an aspect requiring careful examination, particularly in view of its effects on the engine. Moreover, the propeller is coming close to its limits.

The above-mentioned limitations will make a twin propulsion system a viable alternative. Twin-propulsion systems have several advantages such as redundancy and more flexibility regarding partial load. This is important when a port comes in sight. For a design speed of 25 knots, two of the largest twelve cylinder engines installed leads to a mega container vessel of about 15,000 TEU. With even larger engines, the 18,000 TEU Malacca-max container ship will also become feasible. However, twin propulsion systems are significantly more expensive and will require more maintenance effort in operation. (Payer, 2002)

Port limitations

Of great importance for mega vessels are the harbour waters, berths and approach channels, there must be sufficient depth to accommodate the large vessels. A 16.5 meter deep port entrance allows access, albeit sometimes with minimal under-keel clearance, to nearly all containership now in existence. However, mega container carriers need up to 22 meters deep entrance channels. Currently, only a few ports are able to accommodate mega vessels. In the Far East and Europe the draft problem is less imperative than for (East Coast) U.S. ports where the question of how to achieve sufficient water depth is a vexing one.

An aspect often forgotten in the discussion is the problem of ‘air draft’ i.e. the distance between the water surface and the highest point of the ship. At the moment very large containerships such as CSCL’s Asia have an air draft of 61.5 meter, which is close to the clearance of some bridges spanning the port entrance. The Bayonne Bridge in New York is a good example in this respect.

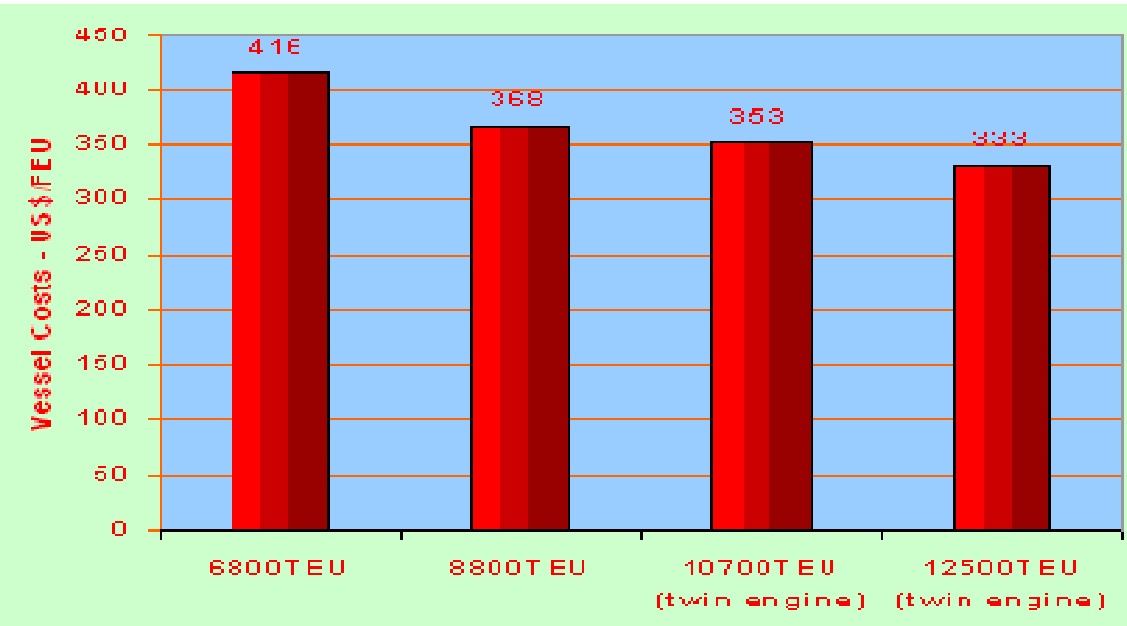
3.2 Logistical implications

Transhipment

Current post-Panamax vessels carry a maximum of 17 rows of containers across deck. Therefore, container cranes must be capable of spanning 17 rows of containers stacked 7 tiers high on deck. The practical limit for a ship of more than 300 m in length is about 5 to 6 gantry cranes simultaneously with a maximum performance of 120 to 150 moves per hour per ship. Albeit 9,000 TEU containerships can be handled by a crane capable of spanning 18 rows stacked 16 to 17 high, new ideas and concepts are needed here to keep pace with the developments of the large container vessels. Further improvement of productivity, can be achieved by increased speed for the crane movements, double trolley cranes and servicing the biggest ships from both sides in a berth. In 2001, such a terminal was constucted in the port of Amsterdam: the Ceres Paragon Terminal.

3.3 Economic aspects

A prerequisite for the introduction of larger container ships is their economic viability compared to today's fleet. This was examined in depth by Ocean Shipping Consultants (OSC, 2000). The clear conclusion was that the trend is upwards to 12,500 TEU capacity. At that point infrastructure limitations constrain the operational flexibility of the vessels. The chart indicates the scale economies per 40-foot container (= 2 TEU), taking into account the major costs associated with trading the vessels, including capital charges, maintenance, crew and fuel. The calculations have been carried out on the assumption that a service speed of 25 knots will be required across this entire range of ship sizes. This necessitates a twin-engine installation for ships of 10,000 TEU and above.



Source: OSC (2000)

Not everybody agrees with the above-mentioned economies of scale in ship costs. Stopford (2002), one of the main critics, opposes the idea of a substantial decrease in cost per container. He states that beyond 5,000 TEU, economies of scale diminish very rapidly. The three key elements in the economies of scale calculation encompass capital costs, operating expenses, and bunker costs.

- Capital costs:

Investors do not save very much capital by building super ships. The cost of the ship increases from $12 million for a 725 TEU ship to $64 million for a 6,000 TEU ship but beyond that there is little further reduction per TEU. So the capital saving per 1000 TEU is quite small. For mega ships the same principle seems to apply. At an anticipated cost of $181.5 million an 18,000 TEU ship costs only $ 10 million (5%) less than three 6,000 TEU vessels.

- Operating costs:

Operating costs, which include crew, insurance, stores, maintenance and administration, also offer less opportunity for economies of scale than appears at first sight. Administration, stores and manning do not increase significantly, so there are scale economies here. However insurance and maintenance costs are likely to increase in line with the capital cost of the ship, offering little scale economy.

- Bunkers:

Finally there is fuel consumption. Regression analysis suggests that increasing a ship's capacity by 1,000 TEU raises the bunker consumption by 31.8 tonnes per day (though a more thorough analysis would take account of the faster speed of bigger ships). So there are almost no economies of scale in bunker consumption, at least over such a wide TEU range.

Moreover, maximising ship size neglects the other costs in the transport chain. Ship related costs only account for less than a quarter of the total door to door delivery cost. The components of these costs consist of:

1. The ship (23%); the share of the above mentioned costs diminishes for bigger ships.
2. The containers; including maintenance (18%); this cost is not directly influenced by ship size but there might be congestion driven diseconomies.
3. Ports and terminals (21%); the port sector certainly faces significant diseconomies of scale due to the cost of dredging as draft is deepened. However, these costs can often be allocated to port authorities since they are eager to accommodate large containerships. In contrast, terminal cost will be fully incurred on shipping lines, especially since they are more and more involved in terminal operations.
4. Inland transport (25%); these costs are not directly related to the size of ship, but there are logistics issues which do not necessarily favor big ships. Generally speaking, a transportation asset such as a ship must be in motion to assure its economic survival. So, liner shipping companies need to minimise port time and mega container carriers will only call at a few hub ports. Some scenarios suggest that 15,000 TEU (or larger) container ships are deployed on the main East-West routes. North-South linkages are maintained with feeder ships from 250 to 6,000 TEU. The most likely locations for the four "mega hubs" in the world are Southeast Asia, the Western exit of the Mediterranean, the Caribbean and the West Coast of Central America. So the region served by a hub port will expand and the cost of inland transport will increase.
5. Other costs, including container repositioning (13%); not ship size related, except possibly some small saving in administration.

4. Empirical research

The introduction of mega carriers of 12,500 to 18,000 TEU-range depends on decisions made by container shipping lines. Their policy regarding the deployment of vessels, hub and spoke networks and ports of call will determine the future of mega carriers. So, what is their idea about the developments in the container sector? Will they use mega container vessels in the future? In order to obtain answers on these questions executives of major container shipping companies, including the top 5 operators, were interviewed. Since Very Large Container Vessels are the workhorses of the Asia-US and Asia-Europe route, shipping lines in Antwerp (MSC), Hong Kong (Hapag Lloyd, MSC, P&O Nedlloyd), Koahsung/Keelung (APL, Evergreen, Yang Ming) and Rotterdam (Evergreen, Maersk Sealand) were interviewed during the first half of 2003. The results are summarised in table 1.

			MEGA CONTAINER VESSEL (12.000 – 18.000 TEU)				
	Fleet (rank)	Biggest vessel (in TEU)	Feasibility		Anticipated problems		
Name					Vessel	Port/terminal	Operations
Maersk Sealand	1	6.600 (or more)	yes	long term	engine	berth length handling capacity cranes (terminals are crucial)	hub-and-spoke inland hubs
Mediterranean Shipping Company (MSC)	2	6,750	yes	long term		waiting time	new calling pattern
Evergreen	3	6,332	no		draft	gantry cranes	
P&O Nedlloyd	4	6,802	yes (technical) no (economical)	long term	engine draft.	terminal facilities, hinterland connections, waiting time	calling pattern (more feedering)
CMA(Compagnie Général Dáffrètement) - CGM (Compagnie Général Maritimes)/	5	8,238	yes	long term		supra- and infrastructure	hub-and-spoke
Orient Overseas Container Line (OOCL)	14	8,063	yes	medium term	engine	dedicated terminals	mature markets
Hapag Lloyd	16	7,506	yes	long term	draft	gantry cranes	hinterland connections more containers

In general, shipping line companies consider mega container carriers feasible from a technical point of view, albeit not in the near future. From an economical point of view feasibility is less apparent. Most shipping lines need to adapt their hub-and-spoke network substantially and therefore reduce the number of ports of call or serve only mature markets. Feedering by smaller vessels and inland transportation will become more important. P&O Nedlloyd considers such type of operation economically not viable. If mega container carriers are introduced huge investments in ports and terminals are needed. Since shipping lines increasingly operate their own terminals, they have to pay for new gantry cranes with an outreach of 24 containers themselves.

5. Conclusions

Undoubtedly, the trend of increasing ship size has not yet come to an end. Growing (Asian) markets require container capacity and shipping lines will provide it. Technically speaking mega carriers are feasible but from an economic point of view the benefits are small. Momentarily traditional concepts are stretched to its limits. Obviously, the new generation container ships are twin screw with two engines. If this is a success the next frontier is the Suez-max vessel up to approx. 12,500 TEU. The ultimate container vessel, the Mallaca-max probably has too many limitations to become a new standard.

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