International
Transport Forum

The Impact of Mega-Ships

Case-Specific Policy Analysis

OECD

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INTERNATIONAL TRANSPORT FORUM

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Acknowledgments

This report forms part of an OECD/ITF project on the Impact of Mega-Ships, directed by Olaf Merk. This report is written by Olaf Merk, Bénédicte Busquet and Raimonds Aronietis. Written contributions were provided by Alain Lumbroso (OECD/ITF); as well as Burkhard Lemper, Sönke Maatsch and Michael Tasto from ISL. Visual contributions were provided by Philippe Rekacewicz, Philippe Rivière and Agnès Stienne. Voluntary contributions that enabled the project were provided by the port of Gothenburg, Hamburg Port Authority and IPC (Indonesia). The report has made use of datasets provided by port terminal operators, ports, Lloyds Intelligence Unit and ISL; as well as OECD/ITF datasets.

Valuable comments on a draft version of the report were provided by Stephen Perkins (OECD /ITF), José Viegas (OECD/ITF), Viktor Algurén (Port of Gothenburg) and Ingo Fehrs (Hamburg Port Authority). The report was formatted by Delphine Malbrancq.

The report has made use of insights and data collected during study missions to Hamburg and Gothenburg, as well as interviews with a range of relevant stakeholders. A list of the interviewed people is included in Annex 7. As part of the project, an expert meeting was organised 10 April 2015 in Paris; participants to this workshop are included in the list of interviewed people.

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Foreword

Container ships are the work-horses of the globalized economy: although they represent only one eighth of the total world fleet they are essential for the transport of consumer goods around the world. Container ships have grown bigger at a rapid pace over the last decades, faster than any other ship type. In one decade, the average capacity of a container ship has doubled. The largest container ship at this moment can carry 19,200 containers[1], but ships with capacity of more than 21,000 containers have been ordered and will be operational in 2017.

Larger container ships have generated cost savings for carriers, decreased maritime transport costs and as such facilitated global trade in the past. However, larger ships require adaptations of infrastructure, equipment and cause larger peaks in container traffic in ports, with wide-ranging impacts. This report assesses if the benefits of the current mega container ships still outweigh their costs to the whole transport chain.

This report is part of the OECD/ITF Mega-Ship project. Other publications that will be released within the framework of this project include case studies of Hamburg, Gothenburg and Jakarta.

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[1] Twenty foot containers

Executive summary

- Cost savings from bigger container ships are decreasing
- The transport costs due to larger ships could be substantial
- Supply chain risks related to mega-container ships are rising
- Public policies need to better take account of this and act accordingly
- Further increase of maximum container ship size would raise transport costs

There are cost savings of mega-ships, but these are decreasing and might not even be realized. Doubling the maximum container ship size over the last decade has reduced total vessel costs per transported container by roughly a third. However, these cost savings are decreasing with size; the cost savings of the newest generation of containerships are four to six times smaller than the savings from the previous round of upsizing. Approximately 60% of the cost savings of the most recent container ships are related to more efficient engines and not to scale. In addition, mega-ship development and the related container fleet capacity growth has taken place despite sluggish growth of world containerized seaborne trade. The massive ordering of new mega-ships has resulted in oversupply of container ships, which will most likely dampen some of the cost savings due to larger ships, as low demand results in fewer savings per transported container.

The transport costs due to larger ships could be substantial. There are size-related fixes to existing infrastructure, such as bridge height, river width/depth, quay wall strengthening, berth deepening, canals/locks and port equipment (crane height, outreach). Mega-ships also require expansion of infrastructure to cater to the higher peaks related to mega-ships; as a result, more physical yard and berth capacity is needed. These annualised transport costs related to mega-ships could amount to US$ 0.4 billion, according to our rough and tentative estimations. Roughly a third of the additional costs might be related to equipment, a third to dredging and another third to port infrastructure and port hinterland costs. A substantial share of the dredging, infrastructure and hinterland connection costs are costs to the public sector in many countries.

Supply chain risks related to bigger container ships are rising. There are concerns about insurability of mega-ships and the costs of potential salvage in case of accidents. Mega-ships also lead to service and cargo concentration, reduced choice and more limited supply chain resilience, especially since bigger ships have coincided with increased cooperation of the main shipping lines in four alliances. In addition,

Public policies need to better take account of this and act accordingly. Key question is how the costs for the public sector imposed by mega-ships could be covered. Many ports and countries have, either accidentally or on purpose, encouraged the development of mega-ships. More balanced decision-making would be needed, with clearer alignment of incentives to public interests, policy support to enhance supply chain productivity, more regional collaboration and the creation of an appropriate forum for a discussion between liner companies and all other relevant transport actors.

Further increase of maximum container ship size would raise transport costs. So one could wonder if such increases would be desirable. The potential cost savings to carriers appear to be fairly marginal, but infrastructure upsizing costs could be phenomenal. Introduction of one hundred 24,000 TEU ships in 2020 would require substantial investments in those places where these ships would be first introduced (Far East, North Europe, Mediterranean), but would also - via cascading effects - result in introduction of 19,000 TEU ships in North America and 14,000 TEU ships in South America and Africa. This would imply additional investment requirements there as well.

Policy recommendations

Make more balanced decisions on accommodating mega-ships

Countries and ports frequently make decisions that seem positive on an individual level, but could be detrimental at a collective level. Countries and ports need to consider the costs of accommodating bigger ships in comparison to the overall economic benefits, including port income, savings to local shippers/importers/exporters, and whether such savings will be sufficient to pay for such costs.

Align incentives and costs to public interests and recover costs of mega-ships

Correct any accidental subsidies or misaligned policies that encourage upsizing, or that provide public resources to container shipping without appropriate recovery of costs. Measures could include:

- Design port dues in such a way that they do not provide incentives for the largest ships. In addition, introduce mechanisms to recover dredging costs on users, for example via fairway dues and harbour maintenance fees related to ship size.
- Clarify application of state aid rules to the ports sector and increase financial transparency of the ports sector, to avoid that the public sector picks up the bill imposed by shipping lines.
- Link state aid to the shipping sector (such as the tonnage tax[2]) to commitments of the sector to contribute to covering costs related to mega-ships (such as additional dredging needs).

3. Provide policy support to ports to enhance supply chain productivity and innovation

Policymakers should work with ports and terminal operators to enhance productivity, so as to make best use of their assets. This could include:

- Innovation, technical development, workforce training and skills upgrading. Where possible, public policies could reform labour practices and procedures to enhance workforce flexibility.
- Optimise the use of infrastructure capacity, e.g. by truck appointment systems and incentives for port truck moves during night or at weekends.
- Release peaks at port terminals via dry ports, where space in ports is constrained.
- Consider upsizing of hinterland transport modes, such as allowing for larger trains, double stacking and larger trucks.

4. Consider collaboration at a regional and cross-port level

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[2] A tonnage tax is a favourable tax regime for shipping companies, based on tonnage of the fleet of the company, which can be imposed on shipping companies instead of a regular corporate tax

As container shipping lines increasingly consolidate and cooperate, so could countries, port authorities and regulators at a strategic planning level. This could help strengthen the collective bargaining position of the landside supply chain. Regional or cross-port alignment and coordination on policy could help ensure proper allocation of resources while protecting the interest of the supply chain users. Such collaboration could take place with respect to the following areas:

- Regulation of competition and policy options, which could include whether or how to regulate ship size.
- More coordination between port authorities on future port development and investment, which could include port mergers in fragmented port systems to increase bargaining power, where this is possible without compromising competition.
- More port and freight planning at national and supra-national level, to focus investment in port hinterland links on a limited number of ports. In the case of the European Union this could mean reducing the number of core ports in the TEN-T network.

5. Stimulate an appropriate forum for discussion between liners and transport stakeholders

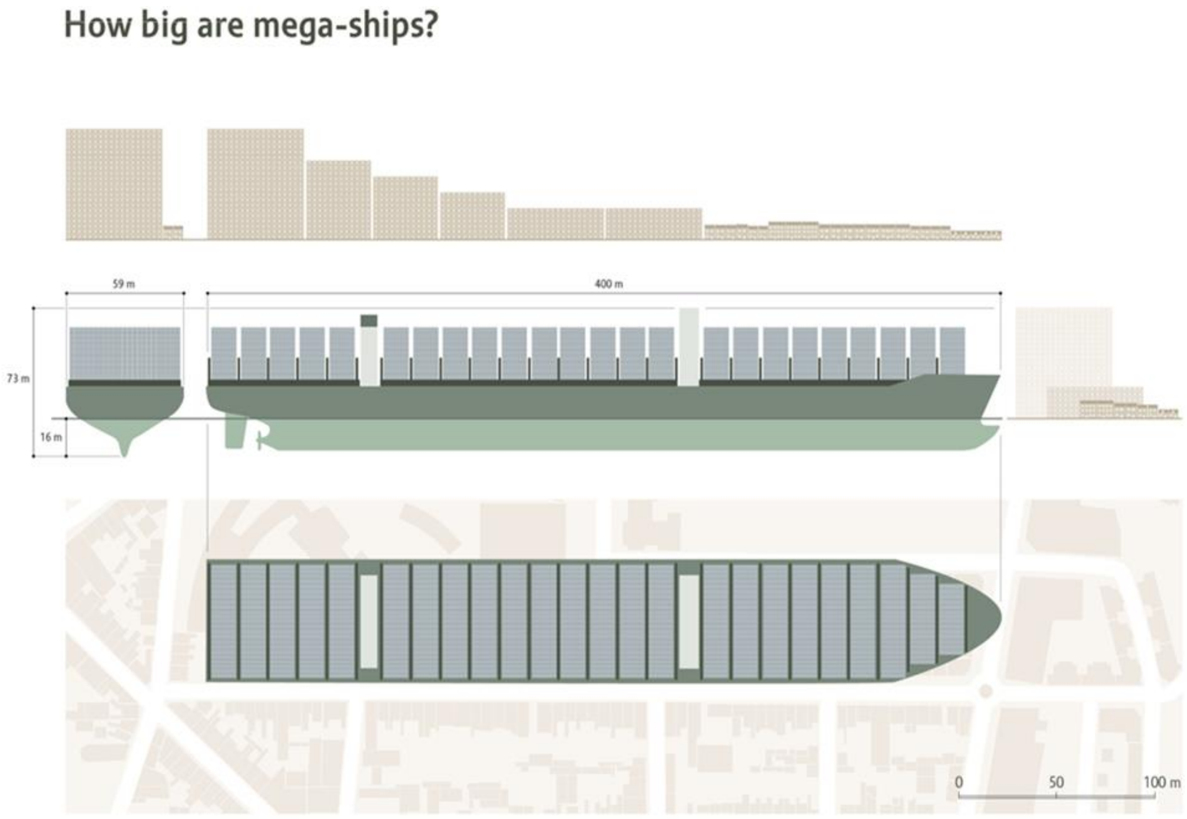
Container lines have typically not consulted anyone on new mega-ships, before they ordered these. A constructive discussion would need to take place with the relevant transport stakeholders, including governments, regulators, port authorities and all interested constituents. The objective could be to facilitate an exchange of views, an understanding of objectives and plans, and ultimately better coordination to ensure optimum supply chain configurations, including optimized use of mega-ships.

Chapter 1. Mega-Ships: Trends and Rationale

Relevance of the subject

Ships are getting bigger. The last couple of years have seen excited media coverage of mega-ships and their maiden calls: longer than four soccer fields, made with more steel than numerous Eiffel Tours etc. The season for big ship announcements seemed to have started: almost every two weeks different shipping lines announce orders for even bigger ships, forming mathematical series that keeps everyone guessing on the next number, when and by whom.

Figure 1.1. **How big are mega-ships?**



Source: Own elaborations

Increasing size of container ships is not a new phenomenon. The last decades have seen an almost continuous increase of container ship size, driven by container shipping lines in search for economies of scale. This was to a large extent facilitated by the invention of container shipping that made cargo handling much more efficient and enabled the increase of ship size. Containerization has undoubtedly contributed to decreasing maritime transport costs. As such it has facilitated global trade, which has had large benefits to many people. However, one can wonder if ever larger containerships still have a positive contribution to society. That is the question that this study aims to answer: what is the impact of mega-ships?

Ship size development might be a different issue than in the past. One of the reasons is the complete disconnect of ship size development from developments in the actual economy. The shipping industry is traditionally a cyclical economic sector, with investments in new ships generally overshooting, creating amplified periods of overcapacity and under-capacity – which is reflected in fluctuating freight rates. The developments over the last years seem different. The orders for the new generation of containerships have been placed in an economic climate that is generally depressed and at best stagnating. Whereas bigger ships since the 1990s could accommodate high sustained levels of external growth, due to the rise of Asian economies, the trade growth to absorb ship developments is currently absent. Shipping lines are building up overcapacity that will most likely be fatal to at least some of them.

Another difference is the quicker pace of up-scaling of ship size. As will be shown in this study, ship size increases have accelerated over the last decade. This increasing pace at which new generations of container ships are conceived and constructed has consequences for the rest of the transport chain: investments in infrastructure and port superstructure are in many cases not yet amortized, which increases capital costs and reduces profit margins for port operators and public authorities.

Moreover, mega-ships create very large peaks in ports and for hinterland transport. This phenomenon is not new, but the scale is unprecedented. It is fair to say that most ports face challenges dealing with these peaks, especially if these occur unexpectedly, e.g. because of lack of reliability by shipping lines. This pain in the supply chain might have reached such heights, that one could wonder if a tipping point has not been reached where further ship size increases result in disproportionally higher port and port hinterlands costs?

In short, ship size has become one of the most burning issues in maritime transport, with repercussions for the whole transport chain. Although widely debated in specialized press and journals, there is currently no comprehensive overview of impacts and possible ways to deal with these; this study aims to fill this gap.

Definitions and scope of this study

This study focuses on container ships. There are various reasons for this focus. Containerships have seen spectacular increases in size, more than most other ship types, as will be illustrated in section 1.4. Container ships represent around a quarter of the total ship population, a share that has increased over the last decades as more goods, including commodities traditionally transported in general cargo ships, reefers or bulk carriers, have become containerized. Moreover, container ships are more than some other ship types linked to hinterland transport, so have more repercussions along the whole transport chain, e.g. more than liquid bulk tankers often connected to pipelines and bulk carriers with cargo directly delivered to industries in port areas.

There are different ways to measure mega-ships. A common measure is the maximum number of twenty foot containers that the ship is able to carry: the maximum TEU capacity. Underlying this TEU capacity are ship characteristics and dimensions that enable this capacity. Container ships are often qualified in different “generations” according to their dimensions. The newest generation of containerships, starting with the Triple E-ships of Maersk, in operation since 2013, has an overall length of 400 metres, a width (beam) of 59 metres and draft of 16 metres. These ships have container rows with

23 containers stacked next to each other. These specifications are important as they determine the characteristics of the port and port equipment needed for handling these ships efficiently. As will be illustrated later, many ports have to make adjustments as ships get longer, wider, higher and deeper. Another measure to some extent related to ship size is gross tonnage (GT), which indicates a ship's overall internal volume. Other somehow related measures are dead weight tonnage (dwt), which indicates the maximum weight that a ship can carry, a measure more frequently used for bulk carriers and tankers than for container ships.[3]

What is considered a mega-ship depends on time and place. There is a considerable academic literature on mega-ship, but the dimensions discussed in the 1990s and even the 2000s are not of the same order. What is a mega-ship also depends on the maritime trade route for which the ship is used. The largest container ships are used on the trade lane between the Far East and North Europe, as will be illustrated below. The maximum and average ship size of other trade lanes is lower, but these ships can also be very large and also present challenges to these ports. As ship size increases, a cascading effect takes place: ships that have become redundant because of the very large newbuilds are deployed on other trade lanes, with subsequent trickle-down-effects up to the trade lane with the smallest ship size. So, the development of ever larger ships not only impacts the trade lanes in which the largest ships are used, but the whole maritime transport chain.

The demand for mega-ships

The development of ever larger ships is driven by the search of economies of scale by shipping companies. Considering that the container shipping industry is mainly driven by price competition – and not very differentiated with respect to other aspects – the decision by one shipping line to increase ship size leads to a wave of similar decisions by competing shipping lines in order not to “stay behind” by not reaping the same economies of scale. The result is a wave of investments in new very large containerships that might make sense from the perspective of an individual company vis-à-vis its main competitors, but less so for an industry as whole, as it results in growth of fleet capacity that is not in line with demand.

Most other actors in the transport chain are not necessarily favourable to mega-ships. Shippers are interested in frequent and reliable maritime transport links, but bigger ships would reduce the service frequency, unless cargo streams growth at the same pace of ship size development; moreover, large shippers might have a preference to hedge risks by parceling out deliveries in different ships rather than concentrating everything in one ship. Terminal operators are confronted with the need to adjust equipment and to handle peaks that are challenging within current configurations. Similar story for ports confronted with new requirements on port-related infrastructure and transport ministries with regards to port hinterland infrastructure and connectivity. Freight forwarders and logistics operators will be concerned with any disruptions or delays of mega-ships that might cause additional transaction and coordination costs. Finally, the peaks associated with mega-ships could cause congestion and delays for truckers, barge and railway companies. A more detailed analysis of the impact of mega-ships on these different elements of the transport chains is provided throughout this study.

Shipping lines generally do not consult with the other actors in the transport chain on their projects. We have not found any evidence of attempts of coordination or prior warnings in this respect. Even container terminals operating within conglomerates with shipping lines have at some occasions been

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[3] There are for example differences in the way in which shipping lines calculate TEU capacity. E.g. Maersk Line quotes the maximum load capacity of their ships in terms of filled TEUs with a 14 tonne load, which will always result in a smaller TEU capacity than the true TEU capacity.

surprised by the ship orders of their mother company – which required them to do retrofits of terminal equipment that was just acquired. One could say that shipping lines have imposed their standards on the wider transport chains, ordering ships with dimensions that other transport actors now have to deal with it. There has been no planned transition. Considering the character of ship size development (in leaps, rather than gradually), what is needed in the related transport chain is a revolution rather than an evolution.

Trends in different shipping sectors

Container ships are the largest ships in the world, at least with regards to length. The overall length (LOA) of the largest container ship is 400 metres, this is longer than the maximum length of current tankers (380 m), bulk carriers (362 m) or cruise ships (360 m). However, container ships have smaller drafts than tankers and bulk carriers, which consequently have higher ship volumes (GT) and weight carrying capacity (dwt). Some of the oil tankers of the past were longer than current container ships (LOA of 458 m), but these oil tankers are no longer in use and have been demolished or found alternative uses.

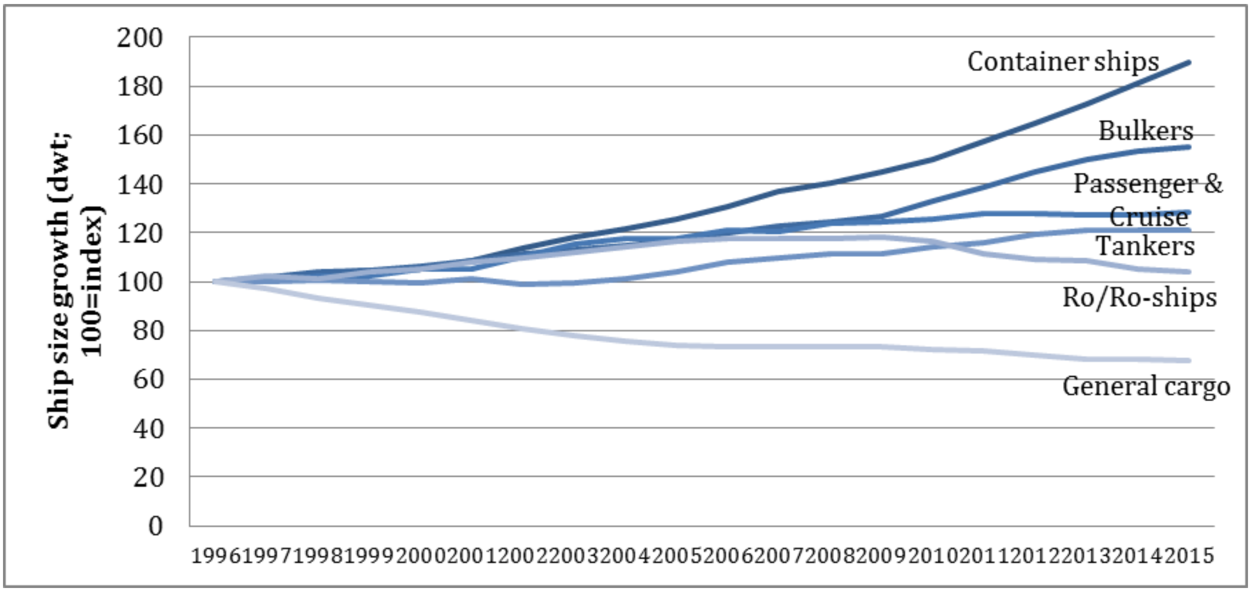
Table 1.1. **Dimensions of largest ships in different ship types**

Ship type	Name	LOA	Beam	DWT	GT	Draft	Since
Container	MSC Oscar	394	59	197,362	193,000	16	2015
Container	CSCL Globe	400	59	184,320	187,541	16	2014
Oil tanker	TI class	380	68	441,893	234,006	24.5	2002
Bulk carrier	Valemax	362	65	400,000	200,000	23	2011
Cruise ship	Oasis class	360	60.5	15,000	225,282	9.3	2009

Source: Own data collection

The size of container ships has been growing at a faster pace than all other ship types. The average container ship size up (in dead weight tonnes) over 1996-2015 was 90%, this was 55% for bulk carriers and 21% for tankers (Figure 1.2). Other ship types, such as Ro/Ro-ships and passenger and cruise ships also grew at much more moderate growth rates, whereas the average size of general cargo ships actually declined.

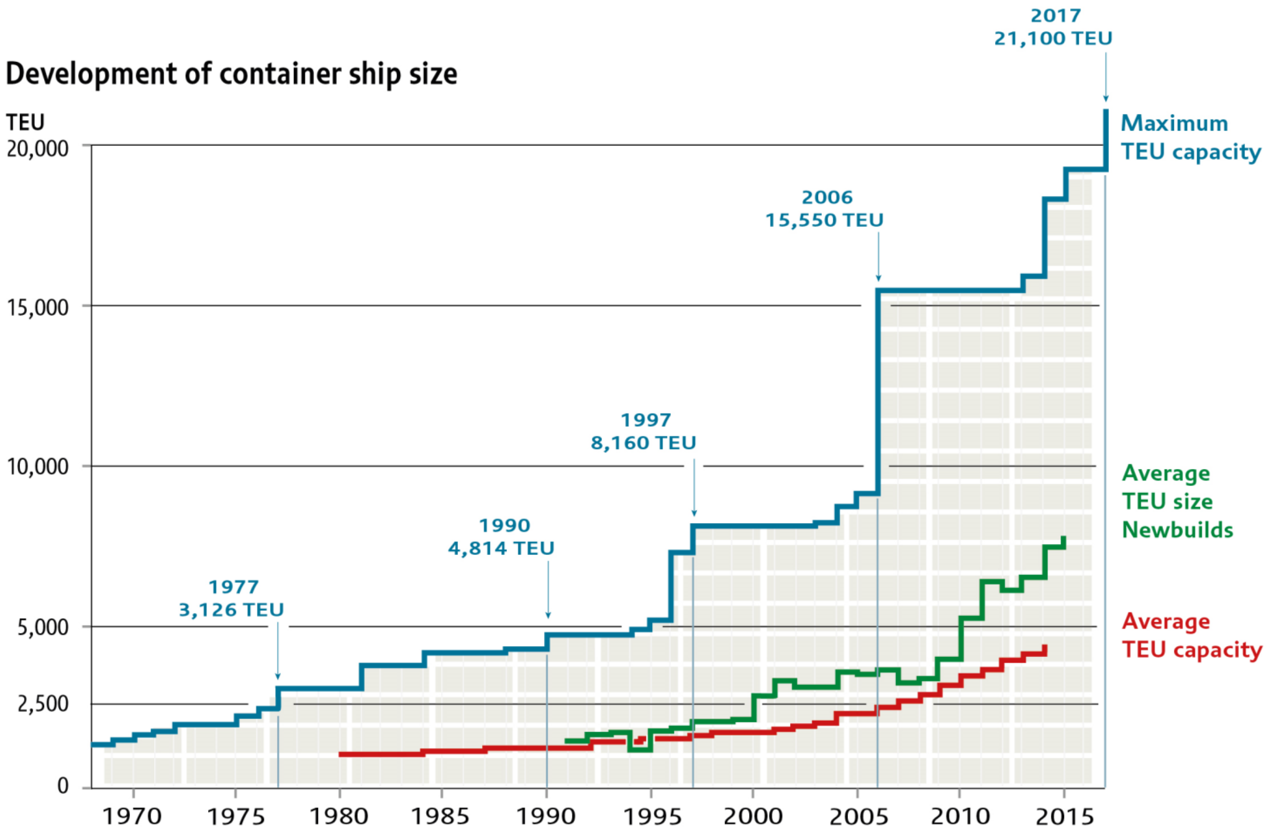
Figure 1.2. **Ship size development of various ship types 1996-2015**



Source: own elaborations based on Clarkson Research Services

The growth rate of containership size has accelerated over the last decade (Figure 1.3). It took one decade to double the average container ship capacity from 1,500 to 3,000 TEU, but almost 30 years to get to 1,500 TEU. This has been driven by large increases in the maximum capacity of container ships, especially in the last decade. These increases in maximum capacity have accelerated the growth of the average ship capacity. The average age of newly built container vessels had been oscillating around approximately 3,400 TEU between 2001 and 2008, but increased significantly since then reaching a mean of 5,800 between 2009 and 2013. The average size of a newly built containership has soared to approximately 8,000 TEUs in 2015.

Figure 1.3. **Development of container ship size**



Source: OECD/ITF based on data from Clarkson Research Services

Both maximum and average size of containerships will grow over the coming years. This can be concluded from the ship orders that have already been placed for ships that are currently under construction and will be delivered over the years 2015-2017. Many shipping lines that have no container ships of at least 18,000 TEU capacity are now ordering new ships, that will over the coming years break new capacity records – that will likely not last very long. In April 2015, the orderbook included 52 ships with capacity larger than 18,000 TEU was 52. Following the delivery of the Triple E-ships in 2013, shipping lines have ordered ships with larger nominal capacity; with the current record in terms of TEU capacity being the 21,100 TEU ships ordered by OOCL.

Table 1.2. **Who has the biggest**?

Shipping line	Name	TEU capacity	Since
Maersk	Triple E series	18,100	2013
China Shipping	CSCL Globe series	19,100	2014
MSC	Oscar, Oliver	19,200	2015
MOL	n.a	20,000	2017 (expected)
CMA*CGM	n.a	20,600	2017 (expected)
OOCL	n.a	21,100	2017 (expected)

Source: own data collection based on various editions of Lloyds List

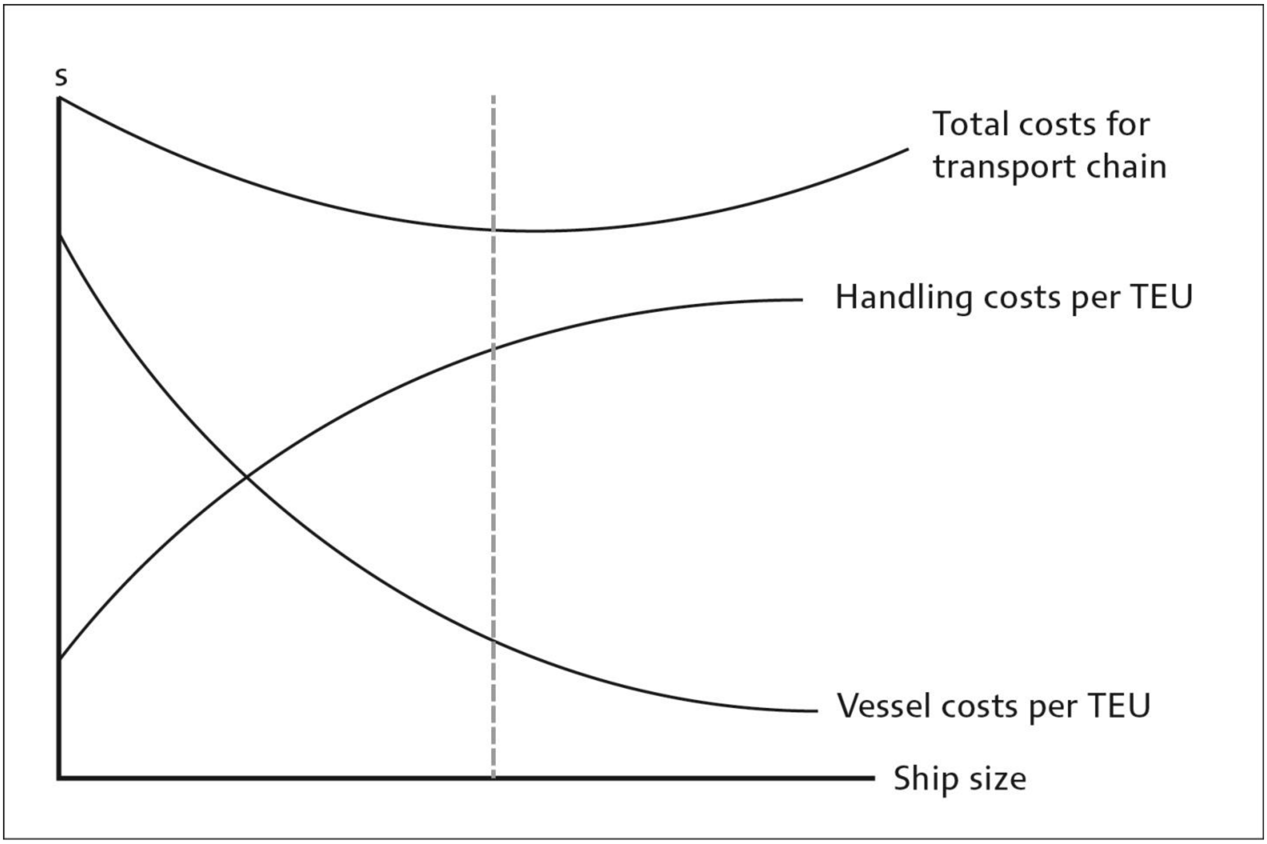
The current generation of containerships could be expanded towards a capacity of approximately 22,000 TEU, with micro-optimisation in new ship design, basically creating additional capacity from within an overall hull size very similar to the Triple-E. These new capacities could for example be reached by adding a top layer and/or an additional container row. Beyond this barrier, a new generation of container ships would be needed.

The next generation of containerships would need to be sufficiently larger to generate sufficient cost reductions; this would mean a capacity of at least 24,000 TEUs. According to some observers this might require a ship length of 456 metres and a beam of 65 metres (Lane and Moret, 2015). A container vessel with a beam of 65 metres will require a higher gauge steel in its primary structure, not only increasing newbuild costs but also adding weight whilst losing space for cargo. Other designs for 24,000 TEU ships come up with different dimensions, e.g. Ocean Shipping Consultants and Lloyds Register conducted a feasibility study on a 24,000 TEU ship with a ship length of 430 metres; a beam of 62 metres and similar draft as the currently largest container ships (16 metres).

Heading towards a disequilibrium of costs and benefits of mega-ships?

There is a fairly extensive academic literature on the optimal ship size, which started to emerge already decades ago when the largest container ships were around a sixth of the current ones (e.g. Kendall, 1972; Jansson and Shneerson, 1982; McLellan 1997; Cullinane and Khanna, 1999 and 2000; Chen and Zhang, 2008; Sys et al. 2008; Tran and Haasis, 2014). Nevertheless, they raise questions that have become even more relevant today.

Figure 1.4. **What is the relation between vessel costs and transport costs?**



Source: OECD/ITF based on Jansson and Shneerson (1982)

One of the key elements raised in these studies is the relation between ship size and handling costs, that is: the cost in the rest of the transport chain related to handle these large container vessels. It is generally supposed that vessel costs per TEU decrease with size, whereas handling costs per TEU increase. The addition of the two curves gives the total transport costs. The question is where we are currently located on these curves, and where we would be heading if container ships would become even bigger. The following chapters aim to give first elements to begin answering this question.

Chapter 2. Mega-ships and maritime transport

This chapter will focus on the cost savings of mega-vessels: how large are these in theory, how large in practice and what are the connected concerns for maritime transport? In order to answer these questions, the chapter sets out the main costs of container ships, calculates the cost savings of the new mega container ships and indicates the limits to vessel cost savings, related to diseconomies from cascading, challenges to fill ships and the oversupply that might be fuelled by mega-ship. The chapter concludes with some concerns related to mega-ships, including industry consolidation, insurability and reliability.

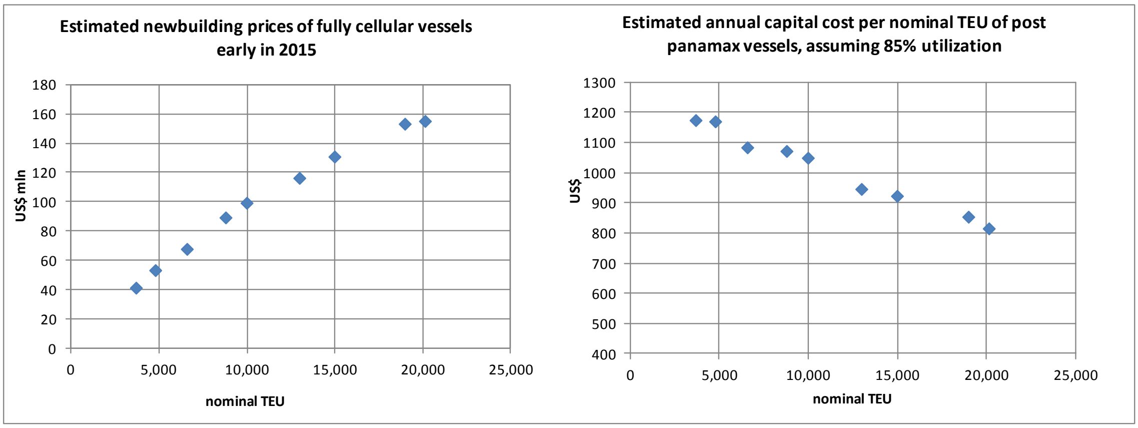
Costs of container ships

The three large cost categories of the container shipping industry are the capital-, operation-, and voyage costs. These respond differently to changes in vessel size.

Capital costs

The available information indicates that the capital costs for the units exceeding 16,000 TEU are actually not increasing in a linear manner but slightly below that. The new paradigm of going slow thus seems to contradict the previous fear that the capital costs of larger units would increase super-proportionally as a result of a second main engine being required to maintain the high operation speeds. Hence, it is fair to say, that the new modus operandi of “slow-steaming” has opened the door for the exploitation of further economies of scale as far as capital costs are concerned. As a result, it is estimated that the ~19,000 TEU units would offer annual savings per TEU-slot (assuming full utilization) of US$ 59 when fully utilized. Assuming a more likely utilization of 85 %, the annual savings per TEU slot of the larger units compared to the previous container ship generation (~15,000 TEU), reach US$ 69. This figure is depending widely on the cost of finance as another per cent of interest will add approximately US$ 7.35 to these savings.

Figure 2.1**. Estimated economies of scale in newbuilding prices and capital cost per TEU early in 2015**

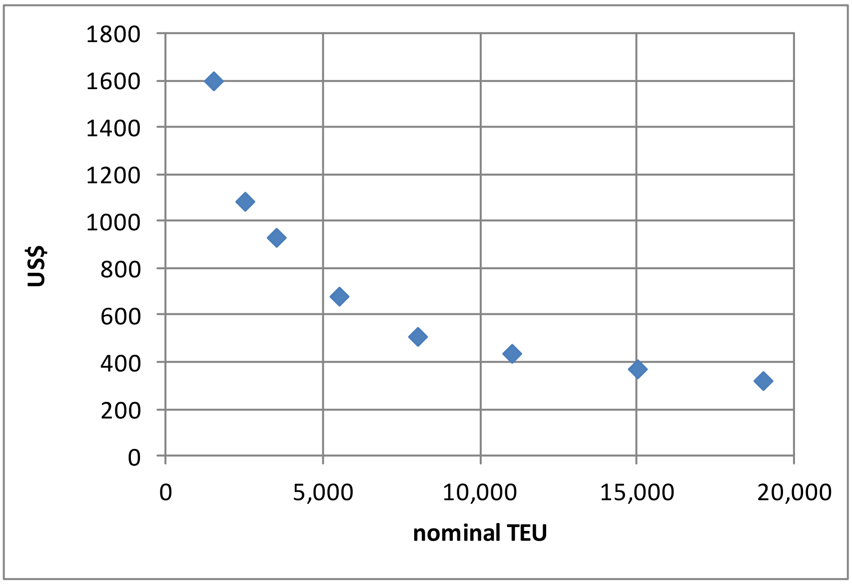


Source: Own elaborations, based on data from Clarksons Research Services Limited (CRSL) and own assumptions/estimates.

Operation costs

In terms of operating costs per TEU p.a., we estimate the annual savings when upscaling from ~15,000 TEU units to ~19,000 TEU units to be US$ 50 (assuming 85 % utilization).

Figure 2.2**. Estimated annual operation cost per nominal TEU – assuming 85 % utilization**

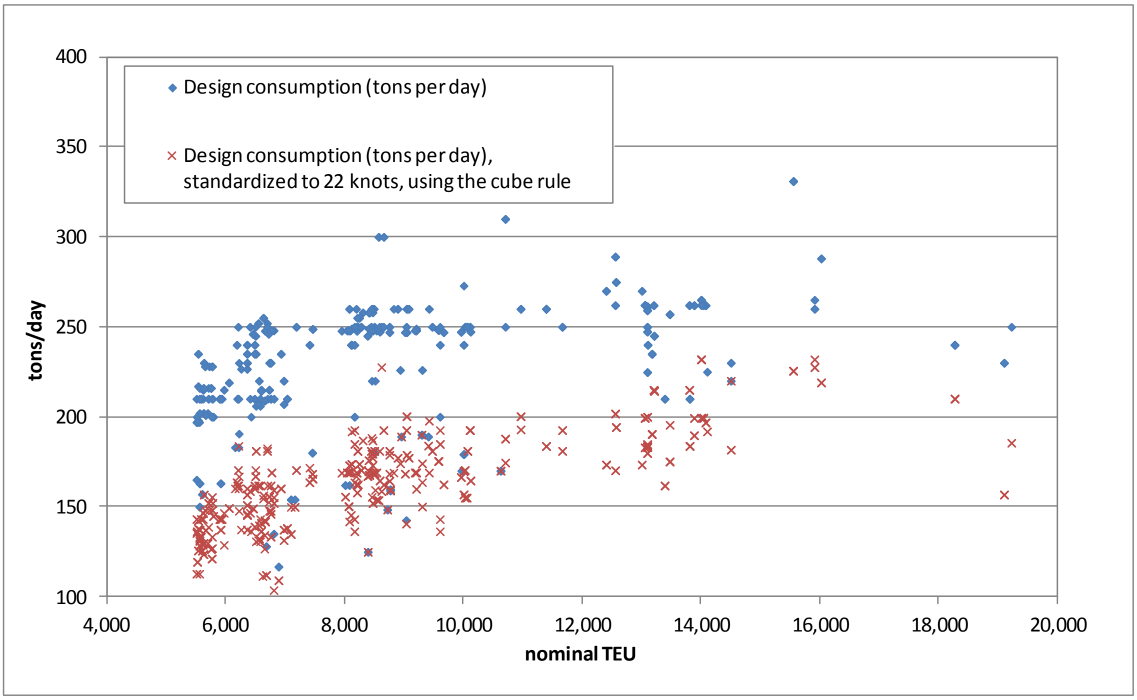


Source: Own elaborations, based on Drewry Maritime Research and own estimates.

Voyage costs

The economies of scale of the voyage costs can be reduced to the single biggest cost driver: the propulsion consumption of the ships. As the speed and consumption patterns of the vessels vary, the daily fuel consumption at design speed (diamonds) which is known/reported/estimated needs to be standardized to an equivalent voyage speed (here: 22 knots, portrayed as crosses) in order to allow for a comparison between vessel sizes. The diagram shows how astonishingly fuel efficient the modern ~19,000 TEU units seem to be, consuming actually less fuel than some of the first ~14,000-~16,000 TEU units which have been ordered and built with a different mind-set.

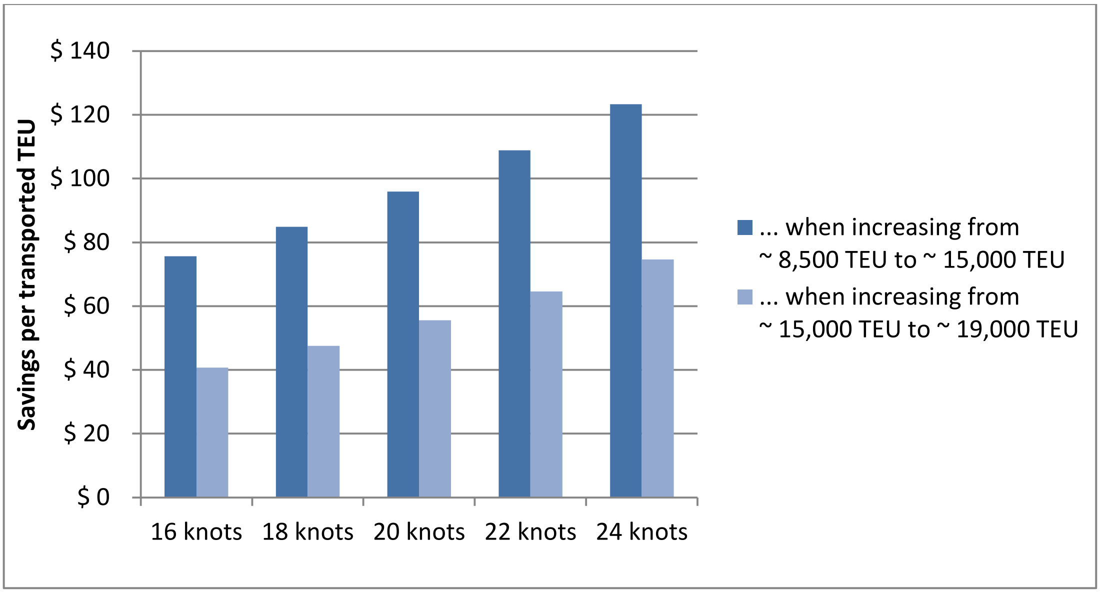
Figure 2.3. **Daily propulsion consumption of the post-panamax fleet early in 2015**



Source: Own elaborations, based on industry data, desk research and own estimates.

Using the collected and estimated data, the impact of the economies of scale for the latest two generations of container carriers can be illustrated. Thereby the vessel is deployed on an imaginary round trip and capital costs, operating costs and propulsion related consumptions are recorded. When analysing the savings per TEU, the modern ~19,000 TEU indeed provide noticeable savings per transported TEU compared to the previous generation of ~15,000 TEU units. Compared to the ~8,500 units, the savings per TEU are reduced by roughly 40-46 per cent though. More extensive details on the calculations and underlying figures are provided in Annex 2 of the report.

Figure 2.4. **Estimated total cost savings per TEU (operation, capital and propulsion consumption)**

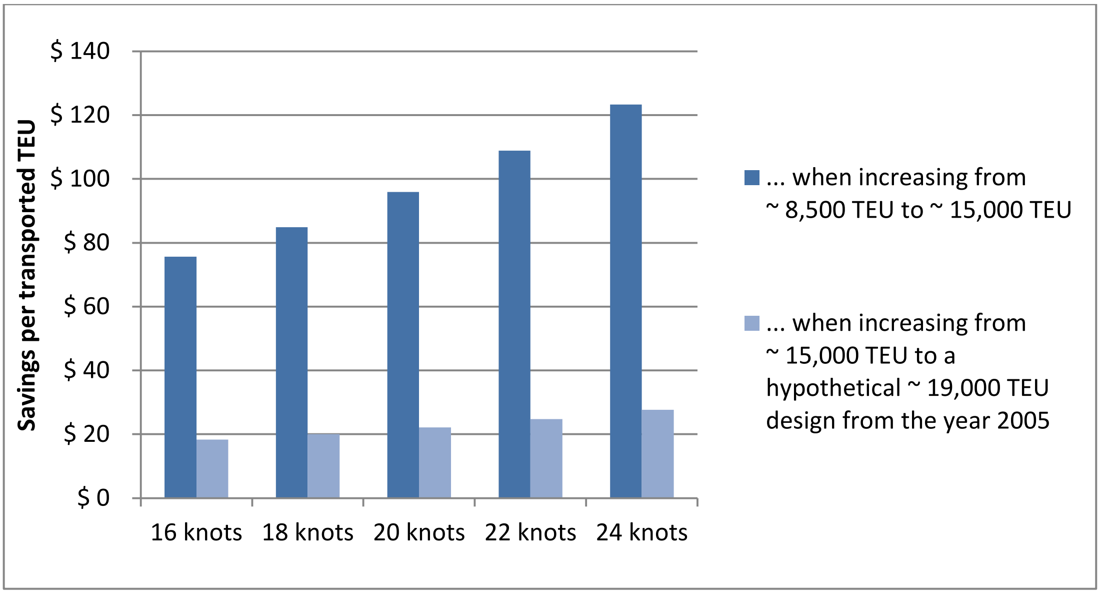


Note: Assumptions underlying these calculations are bunker prices of US$ 600/t on a presumed round voyage of 21,000 nm - comparing units of the latest three generations at 85% utilization

Cost savings of mega-container ships

Most of the cost savings of the largest container ships are not related to size. The ~19,000TEU units provide large economies of scale compared to ~15,000 units but these are widely attributable to the new design and changing modus operandi of the liner shipping industry. Their construction coincides with the emergence of slow steaming in container shipping: voluntarily going slower to save fuel costs and to avoid laying up ships in a context of severe overcapacity. This has two implications: first, the new ships are more efficient at current low speeds than previous container ships that were designed for higher speeds; second, slow steaming has become an inherent feature of the new generation of ships, because they would not be able to go faster if required. A significant amount of the economies of scale of the modern ~19,000 TEU container carriers is attributable to the change in modus operandi of the industry. Using average main engine fuel prices of US$ 600, it can be stated that (at least) between 55 and 63 percent of the savings per TEU when upgrading the vessel size from an early ~15,000 TEU design to a modern 19,000 TEU design are actually attributable to the layout for lower operation speeds.

Figure 2.5. **Estimated total cost savings per TEU (operation, capital and propulsion consumption) with hypothetical fast 19,000 TEU ship**

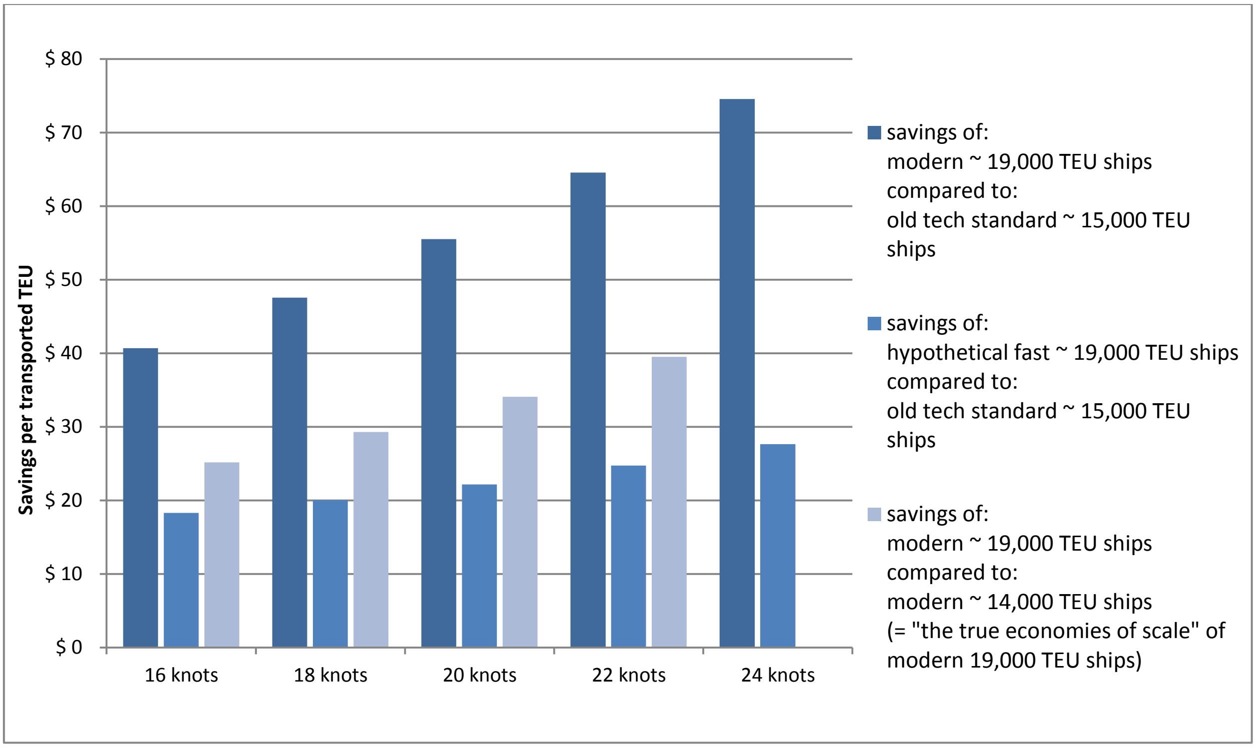


Source: Own elaborations based on assumptions as outlined Annex 2

Note: Assumptions underlying these calculations are bunker prices of US$ 600/t on a presumed round voyage of 21,000 nm, comparing ~8,500 TEU and ~15,000 TEU units with a hypothetical "fast" ~19,000 TEU ship, 85% utilization

Modern 19,000 TEU ships offer significant savings compared to the first 15,000 TEU ships. But (at least) 55-63% of these savings are attributable to optimization for slow steaming. When comparing modern 19,000 TEU units with modern 14,000 TEU units, the true economies of scale of the modern ~19,000 are defined more precisely.

Figure 2.6. **The "true economies of scale" of a 19,000 TEU vessel**



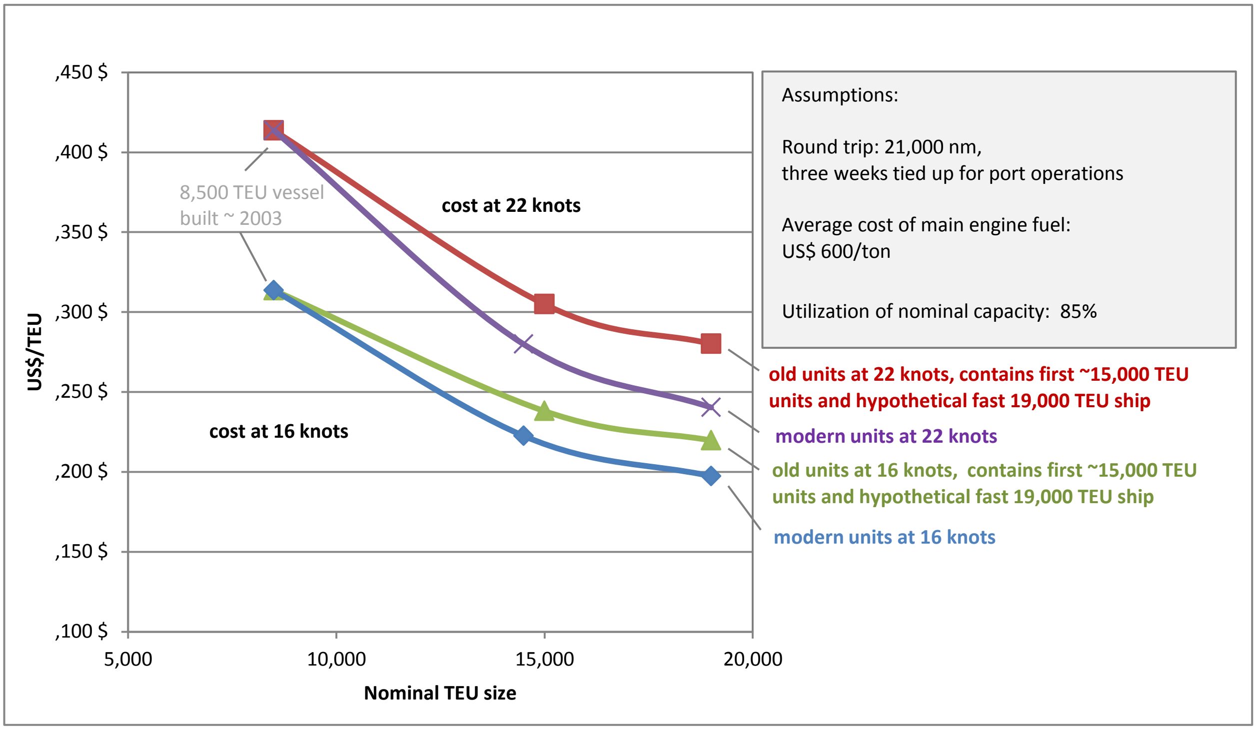
Source: Own elaborations

Note: Assumptions underlying these calculations are bunker prices of US$ 600/t on a presumed round voyage of 21,000 nm - comparing units of the latest three generations at 85% utilization

Savings decrease with size

The cost savings related to bigger scale were large a few decades ago, but the cost savings are decreasing as ships become bigger. A large share of the cost savings were achieved by ship upsizing up to 5,000 TEU, which more than halved the unit costs per TEU, but the cost savings beyond that TEU capacity are much smaller, as illustrated in various studies (Sys et al. 2008; Veldman, 2011). Our analysis confirms that this decreasing cost savings tendency continues with the introduction of the newest generation of container ships. According to our estimates the cost savings of going from the previous to the newest generation of container ships are four to six times smaller than the previous rounds of savings, depending on the assumed vessel speed (Figure 2.6).

Figure 2.7. **Decreasing cost savings of bigger vessels**



Source: Own elaborations

The limits to vessel cost savings

Diseconomies related to cascading effects

The largest container ships are deployed on the Far East-North Europe trade lane, as there is sufficient cargo for this route, but also because this is the trade lane with the longest distance in nautical miles. Most of the cost savings of upsizing of container ships are realised at sea, because it is here that the fuel cost savings take place. As a result, the port time on such trips is relatively limited. Calculations of cost savings by carriers assume that each new generation of containerships will for its whole lifetime be deployed on the same route. As we know, this is not the case in practice, as they trickle down to other trade routes when larger ships come available.

As a result there might be diseconomies related to cascading effects. The extent of these diseconomies remains to be estimated in detail – and would need to be calculated based on actual cases, but the example of the newest generation of container ships can serve as an illustration. The cost savings occur when assuming a total port stay of three weeks for each roundtrip of 21,000 nautical miles. If this ship would be cascaded to a Transpacific trade lane, the voyage is reduced to approximately two thirds of the nautical miles; in order to keep the calculated savings, the port time on each trip would need to decrease from three weeks to two weeks. In case at some later stage the ship would be cascaded to the Transatlantic trade lane, total voyage time would be one third of the originally assumed voyage time: so in order to keep the calculated savings total port time now needs to be one week. One could wonder if this is realistic; although more empirical evidence would be needed to make this point, but it could well be that each round of cascading effects erodes to some extent the cost savings that were realised with the previous round of upsizing of container ships.

Challenges to fill mega-ships

Cost savings of bigger vessels are crucially dependent on the extent to which the ships are being filled. However, the difference in utilization corresponding to a given slot cost is not very large between different vessel size classes. If the utilization rate drops by only 3-5% the cost advantage of a vessel that is “one size” larger will be evened out, according to Grimstad and Neumann-Larsen (2013). E.g. the utilization rate that a 18,000 TEU ship would need to have to achieve cost savings relative to a fully loaded 14,000 TEU ship is approximately 91%.

Shipping lines have difficulties attaining such high utilization rates. In practice most ships are loaded with lower rates. E.g. the monthly ship utilization rates on the Asia to North Europe route have fluctuated between 65% and 103%, which is relatively high compared to other trade routes that generally have lower ship utilization rates (e.g. 52% for the Asia to West Africa route in January 2015).[4]

However, there are large differences between carriers and alliances. The largest ships are built for one trade lane (Far East-North Europe); this trade lane is dominated by three lines that also have links with the main ports in North Europe; however, most other lines now also ordered the largest ships; how are they going to find the cargo? Moreover, the largest shipping lines have a world-wide network, connected to a few transshipment hubs on the Far East-Europe trade lane, where cargo from the Far East could be transshipped to other destinations than Europe; however, most shipping lines lack such a network, so will have more difficulties using these ships optimally. This is illustrated by an analysis of the average ship turn-around time of ships in a large world port, differentiated according to the four alliances (Figure 2.8). This analysis illustrates the large differences between alliances with regards to ship turn-around time (around a factor 2), which might be explained by the complexity of certain alliance structures that could have an impact on the stowage planning of a ship that in turn could impact the turn-around time in ports.

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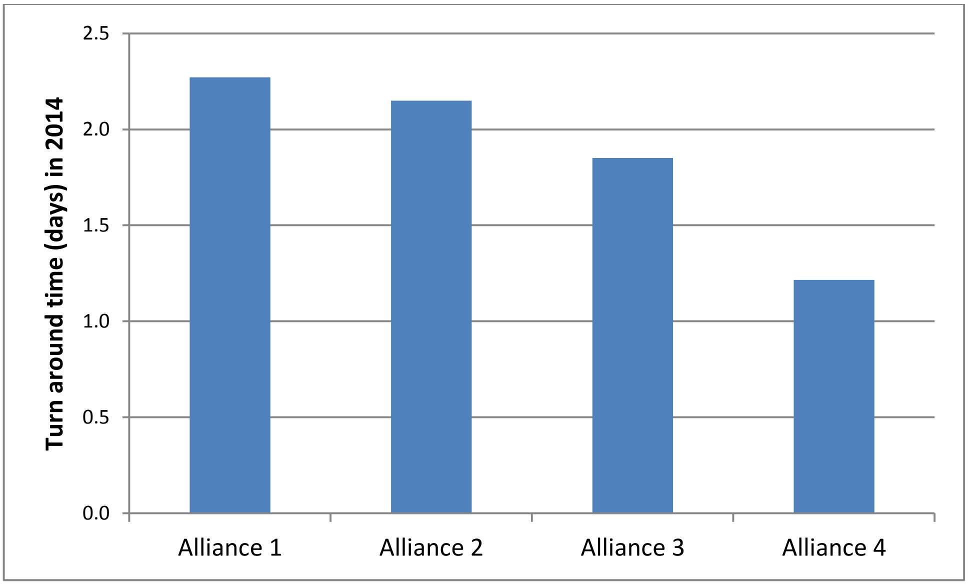
[4] These ship utilization rates represent the utilization of a ship that is already assumed to be loaded at 85% of its theoretical capacity (so 65% of 85%). This 85% maximum is reached when applying the industry rule-of-thump that 1 TEU is roughly the equivalent to 14 tonnes of cargo. The actual weight of cargo is a well-kept secret in the industry, but it can be assumed that containers with light consumer goods weigh less, which would allow a ship to transport more than the assumed 85%. This explains why the ship utilization rate cited in this section can be more than 100%. Evidently, if mostly empty containers would be transported, a ship could also reach its official TEU capacity.

Figure 2.8. **Ship turn-around time of the four alliances in 2014 in a selected world port**



Source: Own elaborations based on own data collection

Mega-ships fuel oversupply of ships

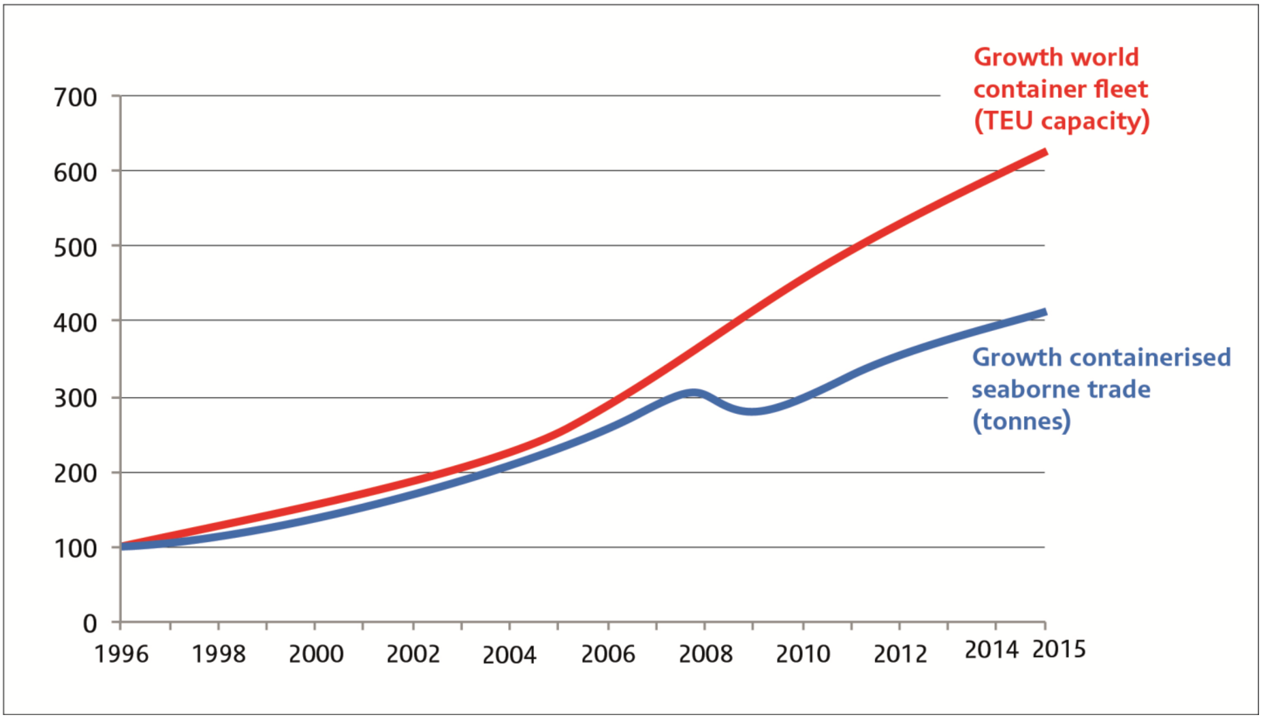
The “herd”-effect after the first orders of the new generation of container ships have fuelled overcapacity of container ships. Container ship capacity has grown at a spectacular rate since 2000, doubling slot capacity every seven years. As a result, total container ship capacity will reach almost 20 million TEUs in 2015, four times the capacity of 2000. Although overcapacity is not a new phenomenon to the shipping industry, and occurring at such frequencies, that it could be considered almost a structural feature of the sector, one could argue that the growing ship size has facilitated overcapacity, especially in a period in which most shipping line perceive they have to catch up in the big ships-race. Adding to this overcapacity is the fact that container shipping provides liner services, so regular, weekly services in a pre-defined set of ports. This means that the number of new large ships corresponds to the number needed to be able to provide these strings; for most Far East-North Europe services this amounts to around 10 ships, when slow steaming.

The acquisition of ever larger ships has been made possible to low asset prices in combination with easy access to finance. Large ships are relatively cheap, not in the least because of conditions of the shipbuilding industry, characterized by overcapacity, fuelled by public subsidies by main shipbuilding nations such as China and South Korea (main producers of the mega container ships). Easy access to finance is particularly the case for the shipping companies that are state-owned companies. These companies benefit from sovereign risk ratings rather than risk ratings related to the sector or their company.

The development of the world container fleet over the last decade is completely disconnected from developments in global trade and actual demand: the growth of world seaborne trade ran remarkably parallel with the growth of average container ship capacity between 1996 and 2007, but has diverged since then, mainly because the stagnant growth path for seaborne trade between 2007 and 2010 was not followed by the container capacity that remained essentially on the same growth path as before and did not adjust for the stagnant global trade developments (Figure 2.9). According to calculations by

McKinsey (2015) there is a gap between supply and demand of approximately 20% that will persist until at least 2019. The effect of this overcapacity is low freight rates, which will undermine the profitability of the container shipping sector.

Figure 2.9. **Disconnection of container ship size developments and seaborne trade growth (1996-2015)**



Source: Own elaborations based on data from Clarkson Research Services

Sea-side concerns related to mega-ships

Industry consolidation is related to bigger ships

Bigger container ships have gone hand in hand with consolidation of the container shipping sector. A sector dominated by the search for economies of scale needed up-scaling of firm size to be able to afford ever bigger ships and be able to fill them. This has taken the form of mergers and acquisitions and alliances. Although there have been mergers in recent years (e.g. Hapag Lloyd and CSAV in 2014), the major consolidation tendency has been the emergence of alliances. In 2011, there were three alliances and six independent carriers; this landscape has changed drastically in 2015 when the same players had formed four large alliances: 2M, O3, G6 and CKYHE. These container shipping alliances represent four fifth of the total world fleet.

This has led to various concerns about the competitive nature of the sector. The proposal for the alliance P3 (Maersk, MSC and CMA CGM) was not approved by the Chinese Ministry of Commerce in 2014 on grounds of the dominant market position that P3 would acquire on the Far-East-Europe routes. The Federal Maritime Commission has also voiced concerns about 2M, the successor to P3, with a one of the commissioners opposing the alliance. In some way, one could consider that the alliance structure perpetuates the fragmented nature of the industry, as it minimizes consolidation considering that is allows smaller players to remain in the game. It should also be noted that the container shipping sector is much less concentrated than other shipping sectors, such as the cruise sector.

Despite industry consolidation, many shipping lines still have difficulties making profit. In 2014, only half of the main container shipping lines recorded an operating profit, most of which fairly marginal. The only shipping lines with higher profit margins were niche players like Wan Hai and (to a lesser extent) OOCL, and the largest carriers: Maersk, MSC and CMA CGM, considered the shipping companies with real returns to scale. The search for economies of scale by container shipping lines has left them investing in very large ships, building up large debts in the process. The container shipping industry would need a new cycle of consolidation and more extended for of cooperation in alliances (smarter alliances) in order to reap more economies of scale and become profitable according to some industry observers (BCG, 2012 and 2015; McKinsey 2015).

Insurability

Mega-ships increase loss potential mainly on two grounds. First the costs to salvage hulls of largest existing containerships in case of accident will increase because of the lack of salvage equipment and technology capable of removing a wreck of this size. There are also very few ship yards in the world capable to repair these ships, which would cause great problems in the case of an accident far away from these. This implies that costs of such scenarios for insurers cannot even be precisely defined. Second, exposure to risk for shippers also increases in a linear way with the capacity of ships. It can be assumed that costs of total losses in case of sinking would be doubled for a 20,000 TEU vessel, compared to a 10,000 TEU vessel. Large shippers take more risks by shipping all of their goods on one vessel instead of dividing these over several smaller ones.

Calculations of possible scenarios indicate potential losses up to US$ 1 billion in case a 19,000 TEU container ship would capsize and sink (Allianz, 2015). A scenario that is described as ‘quite rare”, namely the collision of a mega vessel with a smaller vessel could have costs exceeding US$ 2 billion if there is wreck removal in a difficult location. It has been estimated that it could take two years to remove all the containers from a 19,000 TEU ship in the event of an incident, assuming that it was possible at all (Allianz, 2015).

Insurance companies are being increasingly careful when defining their contracts for mega-carriers and international ship building regulations are toughening to avoid accident risks. Since such events are fortunately unprecedented so far it is hard to anticipate their consequences for the insurance market. This tends to undermine their inclusion within insurance contract. Even if it can be assumed that certain risks exist, they are generally not included in the risk premium, because of weak market for ship insurance and underwriting at the moment.

Reliability and service frequency

Reliability of the container shipping sector is a structural challenge that has not been solved yet. Over May 2014-February 2015 the average East-West ship reliability was approximately 60%, but there is considerable variety according to month and trade route; over the same period reliability ranged from 35% (January 2015 on Transpacific trade lane) to 80% (August 2014 on the Transatlantic trade lane) (Drewry, 2015). Problems of reliability of container ships are amplified when the ships are very large. In addition to that, the frequency of direct calls on the main trade lanes has declined over the last years; the number of weekly Asia-North Europe loops decreased by 36% between 2012 and 2014, with weekly port calls on this trade lane decreasing with 20% over the same period (Drewry, 2014). This is directly related to larger ships.

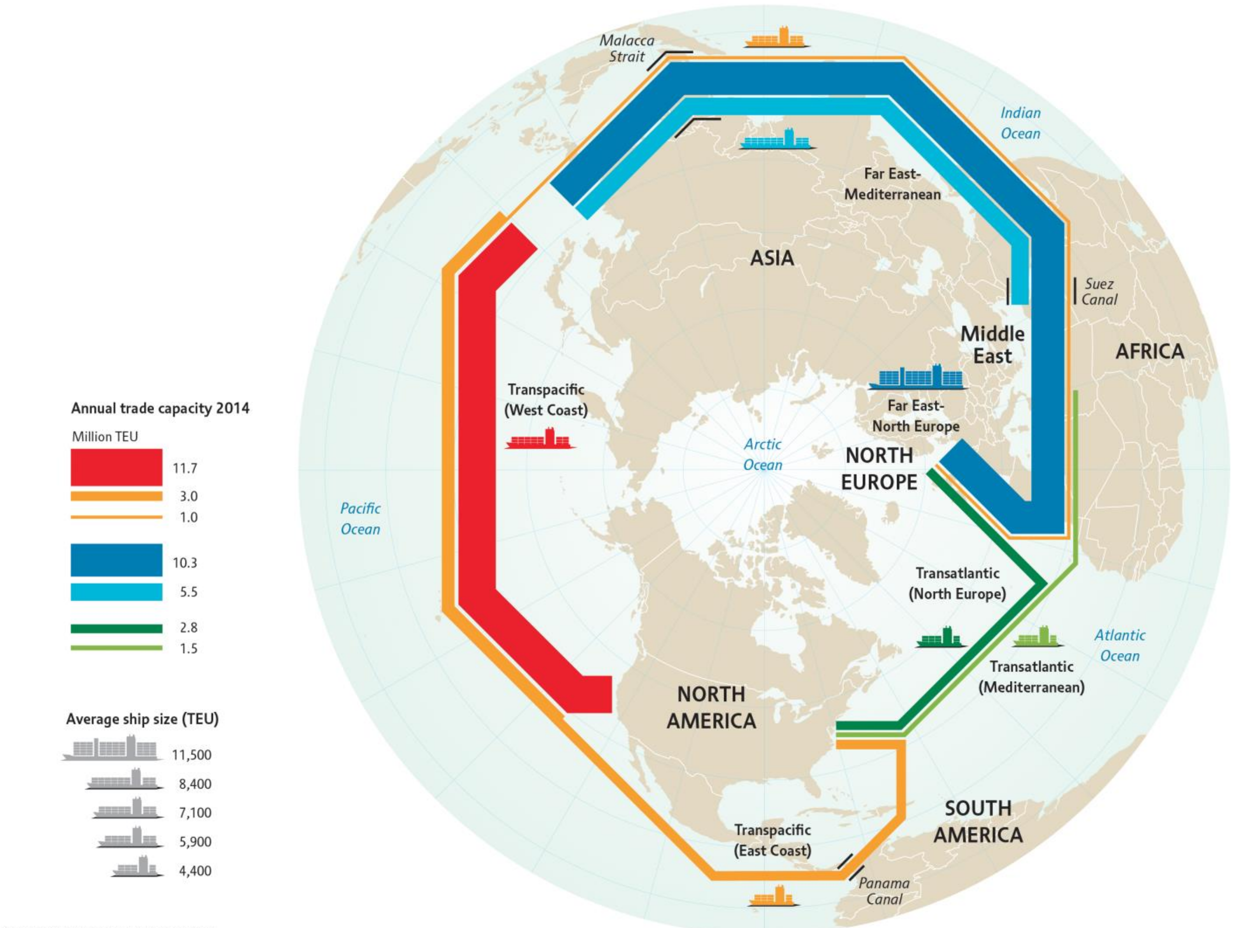
Chapter 3. Ports and infrastructure adaptations

Mega-ships have mega-dimensions, which pose challenges to ports and require adaptations. This chapter will assess main port infrastructure adaptations that might be required to mega-ships. The chapter starts off with an overview of the main trade lanes and ports for large container vessels, followed by an analysis of main barriers to access ports related to depth, locks and bridges. Another section gives an overview of some of the other infrastructure fixes related to mega-ships, namely longer and stronger quays and higher and longer cranes. The chapter concludes with three scenarios for the composition of the global container fleet in 2020 and the impacts this might have on ports.

Main trade lanes and ports for mega-ships

The largest container ships are used on the Far East-North Europe trade route; this is the main maritime route between Asia and Europe. The average ship capacity on this route is 11,500 TEU (Figure 3.1), an increase of 62% between 2007 and 2014, one of the largest increases in ship size. Other trade lanes with large ships include the Far East-Med and the Transpacific (West Coast). Also on these trade lanes, the average container ship size has increased quickly over the last years, in particular on the Far East-Med trade lane, where the average container vessel increased by 79% in size over 2007-2014 (Dynamar, 2015a). The larger ships on the Far East-Europe routes has cascading effects on other trade lanes, with vessels previously used on the Far East-Europe route, being redeployed on Transpacific routes. The average growth in container ship size between the Far East and the West Coast of North America was 54% over 2007-2015; this growth was less pronounced on the route between the Far East and the East Coast of North America (31%), because of the constraints of the current Panama Canal that put a limit on the cascading to this trade lane.

Figure 3.1. **Ship size on main trade lanes in 2014**

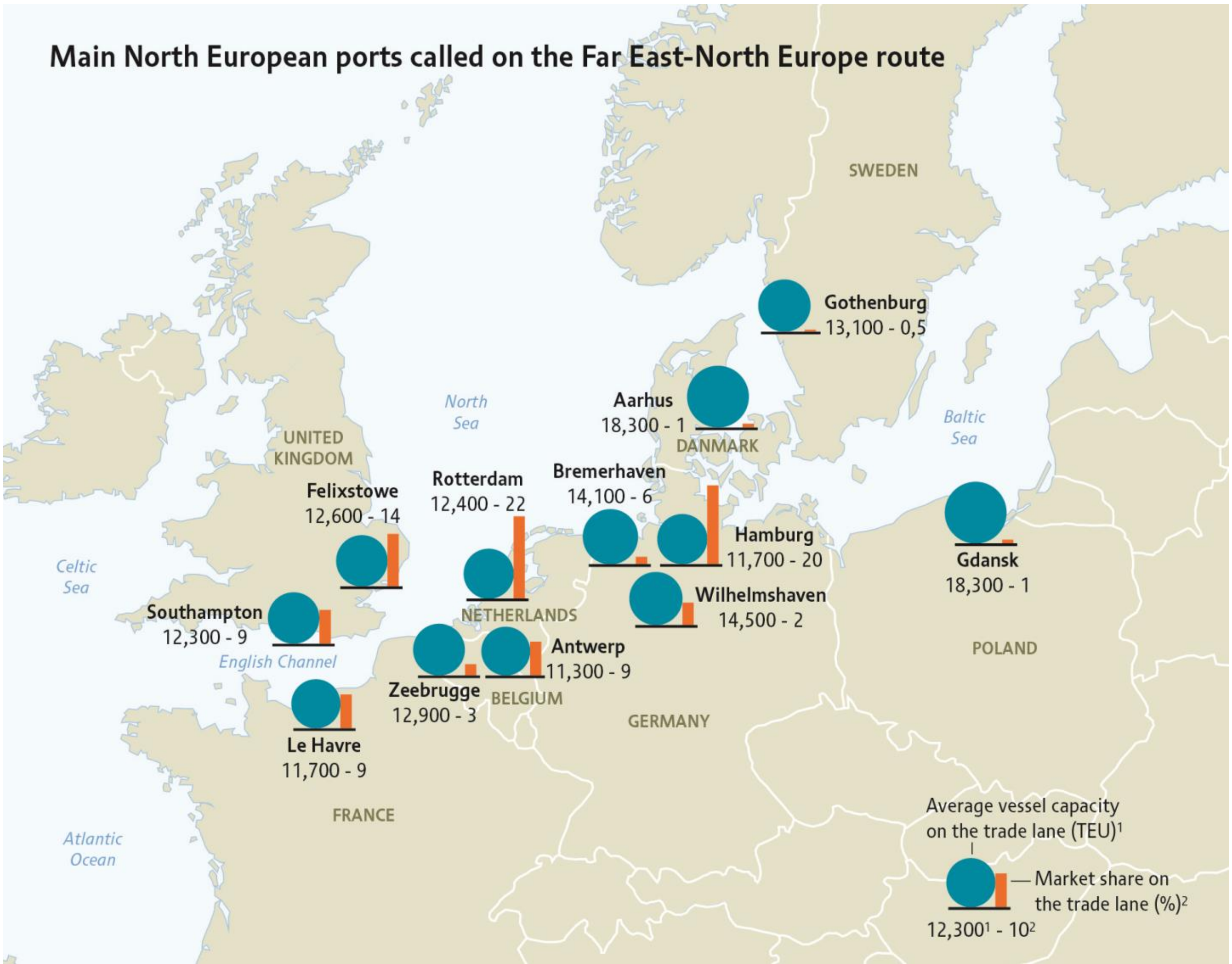


Source: OECD/ITF based on data Dynamar, 2015.

Source: Own elaborations based on data in Dynamar 2015

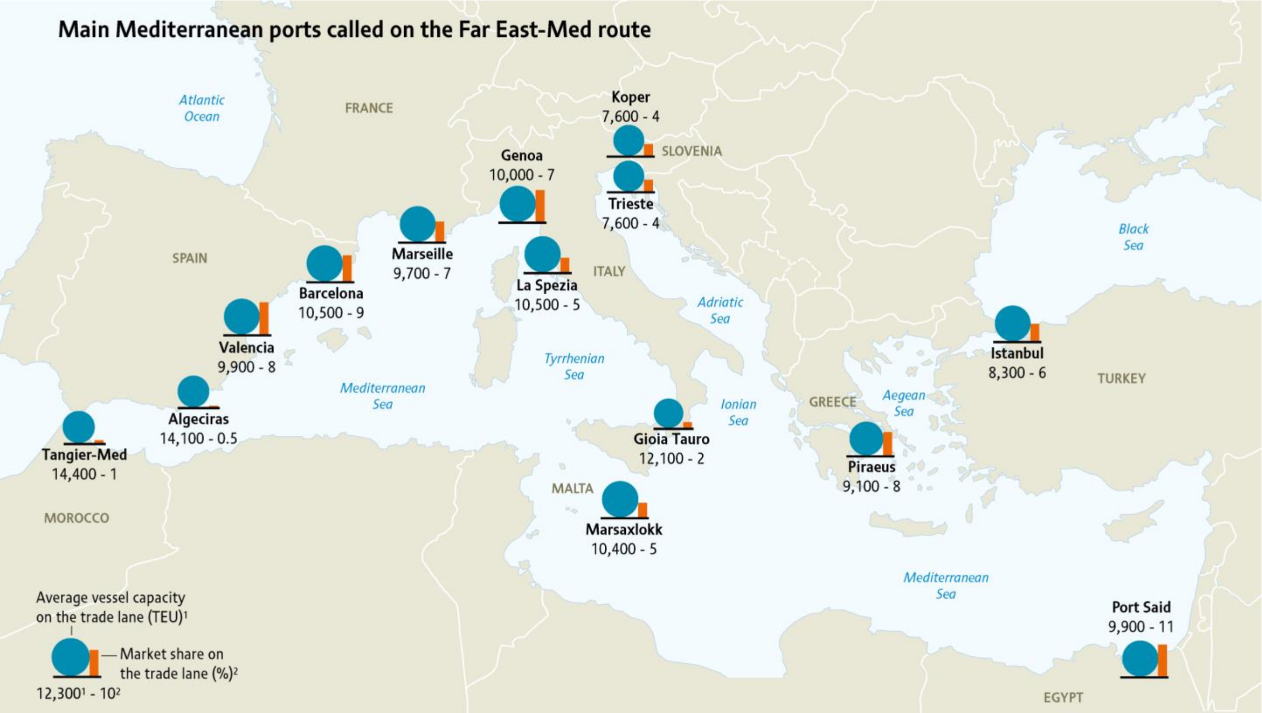
The container ports system has over the last decades become more concentrated. This port concentration has led to some sort of hub and spoke-network, consisting of a limited number of large ports included in main intercontinental trade lanes, with a lot of smaller feeder ports connected to, and in some sense dependent on, this larger port. The emergence of such a hub-and-spoke network is connected to increasing vessel size in the past. This is well illustrated by looking at the main ports that are included in the routes of the largest containerships in Asia and in North Europe, where the majority of calls is concentrated in a select number of ports. E.g. in North Europe approximately four fifth of the direct calls from Asia are in six main ports (Figure 3.1). More or less similar concentration of calls in a selected number of ports occurs in the Far East (Figure 3.4). However, the picture is more fragmented in the case of the Mediterranean ports, with a relatively large set of ports having a fairly low market share (Figure 3.3).

Figure 3.2. **North European ports called on the Far East-North Europe route**



Source: Own elaborations based on Dynamar 2015

Figure 3.3. **Mediterranean ports called on the Far East-Med route**



Source: Own elaborations based on Dynamar 2015

Figure 3.4. **Far East ports called on the Far East-North Europe route**

Source: Own elaborations based on Dynamar 2015

The introduction of a new generation of containerships has for the moment not led to a further port concentration: a similar number of ports are included in strings of 18-19,000 ships, as compared to 15-16,000 ships. This might be related by sluggish demand that makes it challenging to fill up the very large containerships. Additional explanations might relate to the complexity of filling very large ships and the prohibitive costs of feeder legs or land transport legs needed in case there is no direct port call. It is the question if the current period is a transition period towards more port concentration, or if the current situation could be considered an equilibrium situation.

All main ports in North Europe and Far East will have at least one mega-ship (>18,000 TEU) every day after full delivery of the current order book in 2017. The larger container ships on the Far East-North Europe route trickle down to all other trade routes. In case container fleet capacity will grow at similar rates as over the last decade, it is reasonable to assume that by 2020 there will be approximately 135 mega-ships with capacity larger than 18,000 TEU.

Maritime choke points for mega-ships

The main containerised trade flows are East-West flows, which come together in and are to a more and lesser degree constrained by three main choke points: the Panama Canal, Suez Canal and Malacca Straits. At this moment, only the Panama Canal is a real constraint: at this moment only ships with a maximum capacity of 5,000 TEU are able to sail through this Canal. Current expansion of the Panama Canal will increase the size of the container ship able to pass through the Canal. The main constraints related to the Panama Canal relate to the dimensions of the locks in the Panama Canal that are limited in length and width. Potential constraints of the Suez Canal relate to width of two very large ships passing each other, but the new Suez Canal currently constructed will solve this bottleneck, as well as congestion. The Malacca Straits is constrained with respect to depth (21 metres), which currently forms the maximum depth of very large bulk carriers and tankers (Malaccamax ships). According to some authors this depth limitation would also form the natural limit to further ship growth: a famous study in 1999 argued that the final stage of container ship development would be a Malaccamax container ship, with an estimated capacity of 18,000 TEU (Wijnholst et al. 1999). Current designs for 24,000 TEU ships have a depth of 16 metres, so are not coming near to the constraints posed by the Malacca Straits. Despite talks on the possibility of container transport using the Northern Sea Route, there are no indications that this will be a feasible option for mega container ships any time soon yet.

What are the main barriers to access ports?

Depth

Maritime access can be a challenge for many ports that are not deep-sea ports, such as estuary ports and river ports. Several of these ports have calls from mega-ships, e.g. Antwerp, Hamburg and London Gateway. Larger ships imply a larger need for dredging of the rivers or access channels leading to these ports. In addition to the maintenance dredging to keep channels at the same depth, larger ships also require deeper access that requires more intense dredging. There are at this moment eleven terminals in North Europe that offer water depths alongside of 17 metres. Even deeper depths are available at the Eurogate terminal in Wilhelmshaven (18 metres) and the Euromax 1 Terminal in Rotterdam (19.6 up to 20 metres) (Dynamar, 2015b).

This subject is not black and white, as the needed draft of depends on the tides and the load factor of the vessel; the load factor depends on route configuration. When a ship is not fully loaded it has a lower draft than when fully loaded. For this reason, some ports with relatively insufficient water depths are still able to accommodate mega-ships provided that these are in a position within a port loop that allows for low loads (e.g. being the last port in a Far East-North Europe string). Tidal differences make it possible to find periods in which ships can access to the port even if the access is not deep enough.

Hamburg provides a good example to illustrate access issues. The largest container vessels currently calling at the port can only do so during tidal windows that allow a maximum draft of 14.8 meters inbound. Outside these windows, the maximum draft allowed would only be 12.80 meters. Despite this, the largest container ships with a draft of 16 metres cannot call at the port fully loaded with the current capacity of the Elbe River. The beam of such ships is also increasingly a constraint especially for river ports like Hamburg at which ships cannot pass by one another at some stretches of the river Elbe. The size of this type of vessel is a constant challenge for the harbour master's office and such calls require a lot of beforehand planning. Hamburg Port Authority has invested in a sophisticated IT system to be able to overcome this challenge.

Dredging is a sensitive issue in many places. It can provoke substantial local opposition, related to perceived damage to the environment and eco-systems. In Hamburg, court cases initiated by environmental NGOs have delayed the planned dredging of the river Elbe, and gave gone up to the European Court of Justice. Many dredging works not only deepen access channels, but also widen these. Dredging costs can be substantial and depends on different factors, e.g. the kind of soil. The external costs of dredging (such as the monetary value of environmental impacts) are more difficult to estimate.

Locks

An additional challenge can arise with rivers that have lock systems, as these locks are constrained in size and in many cases need to be replaced or supplemented by bigger ones. One of the possible reasons for the failure to create a container terminal in Amsterdam was a concern over the outdated lock system leading up to the port; one of the arguments for the recently announced investment in a new lock system was that it could attract new container traffic in the future. In Antwerp, the motivation for moving the PSA/MSC home terminal from the east bank of the Scheldt river to the Deurgangdok on the west bank, announced in 2014, was that this would mean that ships could avoid a lock system that was considered a bottleneck for big ships.

Bridges

Due to the increasing air draft of ever-larger ships, bridges can become barriers for the access of ships to ports. Cruise ships have already been showing the limitations that existing bridges impose on access to port terminals. In Sydney for instance, cruise terminals were developed outside Harbour Bridge as it does not allow large cruise ships to reach further within the urban waterways because of its 49 meters clearance. The largest existing cruise ship, the Oasis of the Seas, has an air draft of 72 meters, which means it could not pass under any bridge even those with the highest clearance in the world (between 65 and 73.5 meters). Ship height is also quickly increasing in container ship building. Within current ship designs, ship capacity can be expanded by stacking more containers on top of each other rather than by enlarging the ship's beam and length, which diminishes their possibility to access terminals located behind bridges.

In many cases this means that certain parts of the ports become unusable for largest ships, which could lead to port relocation. Hamburg provides an interesting example. The Köhlbrand Bridge, which completion was finished in 1974 is one of the city's landmark but also an essential gateway for the port with over 30,000 vehicles crossing it each day. It is located in the middle of the port providing access to the container terminals from the rest of the port and the city. Its under-clearance is 53 meters, which means that vessels like Maersk Triple E's that have a above water height of 58 meters already cannot pass under it to reach the HHLA Altenwerder Container Terminal. If this is not an immediate issue for

HHLA that operates other terminals to which access is not restricted in height, it might become so if ship size keeps growing as fast as it has over the last few years. Other similar cases can be witnessed in Europe, such as in Gothenburg were the most of the port terminals were re-developed further from the city center partly because the Älvsborg Bridge has a clearance of 45 meters and is blocking access to the old port terminals.

In some cases, bridges are heightened or replaced to facilitate the arrival of larger ships to the port. The Port Authority of New York and New Jersey is currently undertaking the heightening of the Bayonne Bridge, which was completed in 1931 and strengthened several times up to recently. The Bridge's current height above water is around 46 metres which does not allow ships with a capacity over 7,000 TEU to access the port's terminals. The port authority has therefore launched a $1 billion project to raise its under-clearance to 65.5 meters as well as to enlarge and facilitate its access. In addition to port traffic gains PANYNJ sees this investment as a way to mitigate the environmental impact of ships since the larger and newer ones tend to be more environmental friendly. It is also a way to make traffic safer, to allow access to bikes and pedestrians but also to anticipate by creating capacity for mass transit in the future. The project's expected inauguration should take place in 2018. The Port of Long Beach is undertaking a similar initiative but opted for the full replacement of the Gerald Desmond Bridge in use since 1968. A cost of $1.26 billion it is fully designing a wider and higher bridge (62.5 meters compared to 47 now) to allow larger ships in and to provide more road capacity. Construction of the project has started but completion has already been delayed by two years and cost overruns have been reaching $300 million so far, as the design exercise for such infrastructure is extremely complex given the seismic character of the area.

Building new bridges does not exclusively have benefits for port traffic. PANYNJ and the Port of Long Beach also justify their projects as a way to enlarge existing bridges, which will enable to accommodate more traffic as well as make them safer for users. Extra capacity and safety tends to be needed all the more when the bridge is older. The upgrading of Bayonne Bridge will also include better access to the bridges for pedestrians and bikes and therefore better connect New Jersey and Staten Island for other purposes. However, the need to replace a bridge might be too costly if it has not reached the end of its life-cycle yet.

Other infrastructure fixes

Need for longer and stronger quays

Mega-carriers are putting increasing pressures on existing terminals, which, in most cases, have not been built with the assumption that ship size would grow so fast so quickly. In many ports now, quay walls need to be heightened, strengthened and lengthened for them to have the capacity to accommodate the largest ships and the forces they exercise when these are berthing and moored.

Larger ships tend to have higher drafts. The design of quay walls takes vessel draft as the most important element to determine the desirable retaining height of a quay. If ship size increases, higher quay walls will be essential for ships to call safely. It can be estimated that for a 20,250 TEU ship, the retaining height needed is 25.84 meters (Tisheh, 2015), which is significantly more than what is available at a great number of port terminals that are a few decades old or older.

Moreover, not only height is impacted by large ships but also quay length, which challenges quay wall design and retaining capacity. This is linked to the fact that more generally, ship size increase has very important implications for the strength of the quays. A quay wall has several essential functions for safe ship calls at terminals. It must have adequate bearing, berthing and mooring capacities to guarantee safety at the port. The increasing size of vessels has an impact on all these elements and therefore on quay wall requirements and design.

Higher and larger cranes, container handling equipment and stacks generate the need for more quay wall bearing capacity. A quay wall's bearing capacity corresponds to the vertical and horizontal forces exercised by all the loads present on the quay, which can be measured in kilo-newtons (kN) per square meter. As an indication, the cranes that operate the Euromax Container Terminal in Rotterdam, able to reach up to 23 rows, each have a surcharge load of 2721 kN per square meter on the land side of the quay. When they move along the quay they equally spread these forces, while it is not the case when they are operated. Containers also contribute to surcharge load. The maximum weight of a full container is equivalent to a 350 kN load on the quay, which translates into up to 75 kN surcharge load per square meter if five containers are stored on top of each other (De Gijt and Broeken, 2013). Designs of quay walls with a bearing capacity of up to 100 kN per square meter are considered to accommodate future ship size increases.

Quay walls are also under pressure simply because the larger the ship, the larger the displacement created and the more energy to be absorbed. Bollard forces, the line forces generated by moored ships on quay walls, are calculated in function of their size. They are an important part of quay wall design and also enable to define adequate technology needed to fasten ships when they are at berth. Mega container ships generate water displacements over 250,000 tons which translates in bollard forces of over 2,500 kN on quay walls (Tisheh, 2015). Eurogate terminal in Hamburg is said to be able to accommodate a bollard pull of 1,200 kN (per tow-line), which makes it one of the strongest in Europe. This is supplemented by berthing forces, or the kinetic energy produced by ships when approaching the berth to moor (measured in kilo-newtons meters, kNm), which will determine the energy fenders have to absorb. For a large container vessel, with an approach speed of 0.1 meter per second, and a 5° angle, the berthing energy released on the quay is 1595 kNm (Tisheh, 2015).

All these elements imply that previous requirements concerning quay walls are shifting with ship size increase, which challenges the capacity of some terminals to accept calls from very large vessels unless they decide to upgrade their quay walls. This requires very intensive capital and time investments. Soil and weather conditions have important impacts on the quay wall technology required, so costs can vary significantly from a port to the other. However, costs for a new structure can be estimated thanks to the basic costs of building materials and defined requirements thresholds relating to ship size. Calculations for the port of Rotterdam show that the cost of new quay walls for deep sea container vessels would vary between 23,545 euros and 44,400 per running meter for various types of quay wall structures, retaining heights and surcharge capacities (Tisheh, 2015). Generally, retaining height is the most important factor in price determining it to up by 75% in the case of Rotterdam. The higher the quay wall the mostly costly it will be. Surcharge loads will also have an impact on construction costs by up to 10% (De Gijt, 2010). Other than construction costs, building a new quay wall will also generate a number of other costs related to design, engineering and dredging but also a total interruption of traffic during construction generating consequent throughput losses for the terminal.

Cranes

Larger ships pose challenges to cranes in terms of outreach and height. The newest mega-ships require a crane width that allows for handling 23 container rows. One of the increases in TEU capacity in comparison with the first Triple E-ships is stacking one row higher (11 high instead of 10), which means that various container terminals would need to be higher as well. These challenges can sometimes be resolved by certain "tricks", but these provide in many cases only a temporary solution. Solutions to reach the box out of gantry reach vary from swinging the ship from port to starboard along the quay (or vice versa) to slightly heeling the vessel. It also appears that the boom of a gantry crane often has the possibility to go one additional box wide although this then usually goes along with the manual removal of twist locks. A simpler way is to take the restrictions of a reduced crane outreach into account in the vessel's stowage plan (Dynamar, 2015b). At the end of 2014, there were 31 terminals in 14 ports in North Europe handling ultra large container ships. Of these 31 terminals only 16 were capable of handling these ships of 18,000+ TEU without tricks in terms of gantry outreaches.

Some ports are prepared for even larger container ships than the ones that are foreseen for 2017. There are North European ports that currently have STS cranes with 25 boxes outreach (London Gateway and Wilhelmshaven) and four other ports will have these in the near future: Rotterdam, Antwerp, Felixstowe and Gdansk. There are currently in North European ports 107 gantry cranes that can go 23 to 25 boxes wide, while no less than 273 units are planned or expected to join them in the 2015-2024 period (Dynamar, 2015b).

Impacts of a next round of larger ships

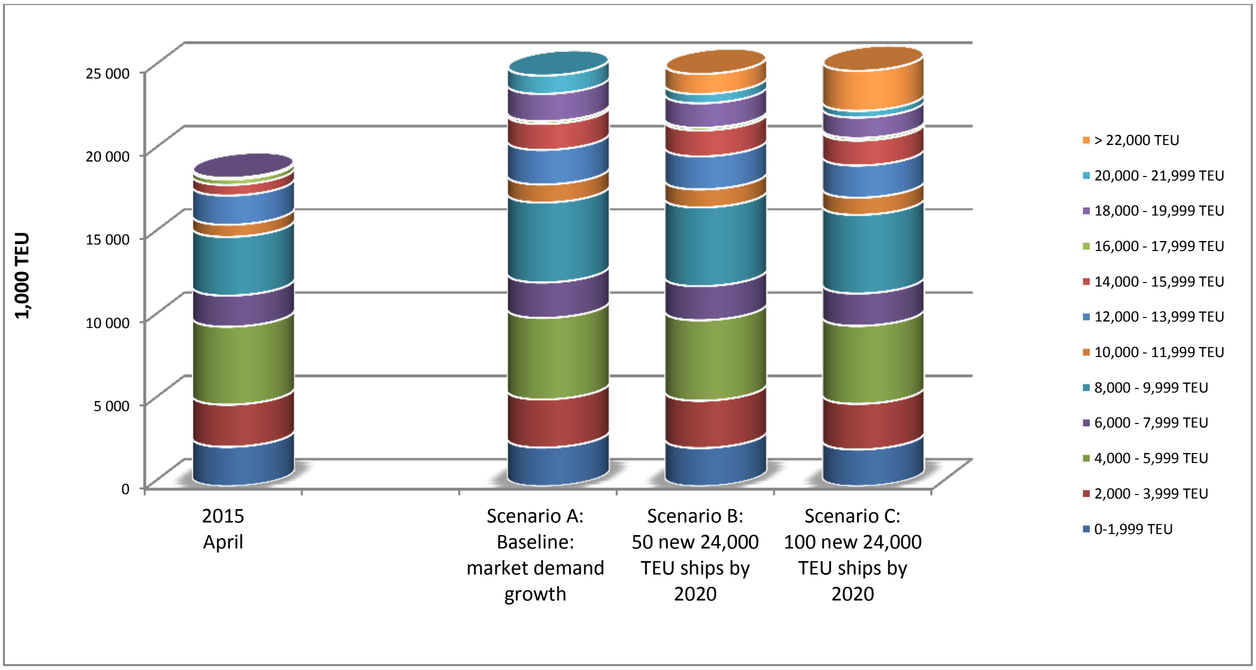
It is likely that at some stage 24,000 TEU ships will be sailing the world oceans; it is not unimaginable that this will already be the case in 2020. This is of course speculation; these are strategic orientations of carriers that they are not willing to share. What follows is in one sense a "thought experiment" to see what could be the impact of 24,000 TEU on average and maximum ship size on main trade lanes; in another sense these are scenarios that could become reality. The following "what-if"-scenarios have been developed as a part of this study:

a) Baseline scenario. The capacity of the fully cellular fleet will grow in line with the market demand growth during the next five years. Thereby the total fleet capacity will expand by roughly one third and contains no units of a new generation of mega carriers with capacities of up to 24,000 TEU by the year 2020.

b) The capacity of the fully cellular fleet will grow in line with the market demand growth during the next five years. Thereby the total fleet capacity will expand by roughly one third and contain **50 units** of a new generation of mega carriers with capacities of up to 24,000 TEU by the year 2020. The new 24,000 TEU units would to a large extend replace investor demand for ~19,000 TEU ships and on their own contribute a million TEU to the growth of the supply side.

c) The capacity of the fully cellular fleet will grow above market demand growth during the next five years. Thereby the total fleet capacity will expand by roughly one third and contain **100 units** of a new generation of mega carriers with capacities of up to 24,000 TEU by the year 2020. This is a very aggressive assumption and the competitive implications would be severe, leading to a spontaneous spike in tonnage surplus und thus trigger a further round of additional scrapings of older and smaller units. Also, the sudden spike in orders for these vessels would imply a strong shift of orders from the otherwise expected orders for 18,000-21,999 TEU vessels.

Figure 3.5. **Capacity shares of 24,000 TEU vessels and other size-classes in the year 2020 by scenario**

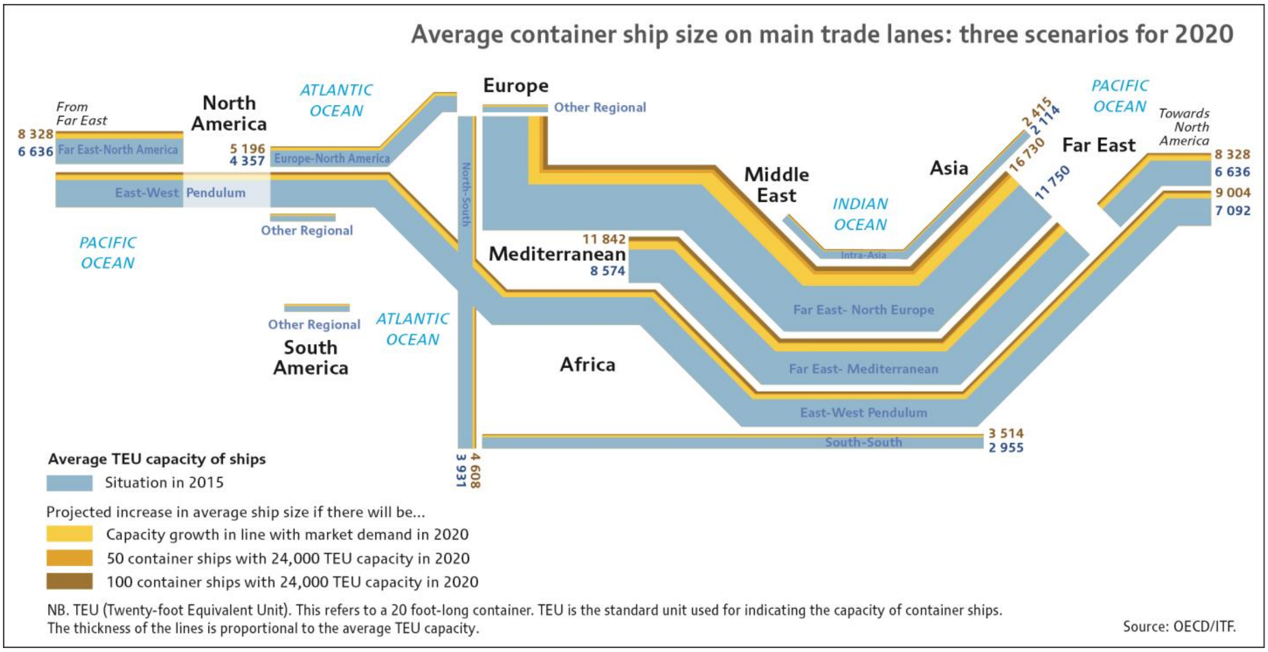


Source: Own elaborations based on data from Clarksons Research Services Limited (CRSL), own scenarios.

In the modest scenario A, the new mega-carriers (and the other ships in the larger size segment) lead to a continuation of the existing trend towards larger ship sizes in all trade areas. Still, the ship growth is modest and mostly in line with demand growth (i.e. the number of services and the operating concept need no particular change). In scenario B, the ship size increase is a little stronger for the Europe-Far East and Europe-America-Asia trades, but the ship size growth on the Transpacific and Transatlantic trades is not affected strongly. In scenario C – next to the overcapacity issue for the fleet as a whole – the ship size increase on the Europe-Far East trade is far beyond the expected market growth. Therefore, the number of services would have to be reduced. At the same time, the 24,000 TEU ships have a rather limited selection of ports available. Therefore, this scenario would create considerable operational problems and additional feeder traffic or longer hinterland distances. From an economic perspective, it is far from attractive for any of the players involved and could only explained by a sub-optimal Nash equilibrium attained by inefficient market behaviour. The share of post-Panamax vessels will double on Transatlantic and Transpacific trades. Ships exceeding the "New Panamax" dimensions will show up on the Transpacific trade, i.e. on the routes that exclude the East Coast and Gulf ports.

The impact of the ordering activity in the upper segment has an impact on all size classes through the cascade effect, but the impact loses momentum in the lower size classes. The average ship size will increase there, too, but at a much slower pace (Figure 3.6). Though more and more Panamax vessels will be used on regional trades, there will also be a considerable volume of newbuildings in the lower size segments which will satisfy the increasing demand for feeder services. Only a strong increase of scrapping activity could create a size increase comparable to the one experienced in the higher size classes.

Figure 3.6. **Average container ship size on main trade lanes: three scenarios for 2020**



NB. TEU (Twenty-foot Equivalent Unit). This refers to a 20 foot-long container. TEU is the standard unit used for indicating the capacity of container ships. The thickness of the lines is proportional to the average TEU capacity.

Source: OECD/ITF.

Source: Own elaborations

For ports in the different regions, the average ship size is only one component. If they want to compete for the hub status, they need to be prepared to receive the largest vessels that may regularly call in the future. The cascade model gives an indication of which size type the liner companies would like to use if there were no size restrictions in the ports. The results are summarised below.

Table 3.1. **Development of maximum ship dimensions by trade lane 2015 and 2020**

	Max capacity (TEU)				Max length (m)				Max beam (m)			
Trade routes	2015	2020A	2020B	2020C	2015	2020A	2020B	2020C	2015	2020A	2020B	2020C
Far East-North Europe	19 200	**21 999**	24 000	24 000	400	400	**430**	430	59	59	**62**	62
Far East-Mediterranean	14 000	**21 999**	24 000	24 000	370	**400**	430	430	52	59	**62**	62
Far East-North America	13 400	**19 200**	19 200	19 200	370	**400**	400	400	52	**59**	59	59
Europe-North America	8 800	**13 000**	13 000	**13 400**	340	**370**	370	370	44	**49**	49	**52**
Other East-West	13 800	**19 200**	19 200	19 200	370	**400**	400	400	52	**59**	59	59
North-South	10 000	**13 500**	**13 800**	**14 000**	350	**370**	370	370	49	**52**	52	52
South-South	4 300	**5 100**	5 100	5 100	260	**300**	300	300	35	**38**	38	38
Intra-Asia	14 000	**19 200**	**24 000**	24 000	370	**400**	400	400	52	**59**	**62**	62
Other regional	8 400	**10 000**	10 000	**11 000**	340	**350**	350	**370**	44	**49**	49	49

Source: Own elaborations, based on data from MDS Transmodal
Note: Only if expected value of the number of ships exceeds one, i.e. excluding outliers.

In almost all scenarios, the ship dimensions increase until 2020 on all of the selected trade lanes. , The baseline scenario foresees growth of ship length on all trade lanes, except for Far East-North Europe in the baseline scenario, where we assume that the current 19,000+ TEU ship will remain the largest. For the other trade lanes (except "other regional"), ship length is expected to grow by 20 to 40 metres in the baseline scenario already. As regards ship beam, the Transpacific trade could see a strong increase from 52 metres nowadays to 59 metres in future, i.e. by 3 rows to 23 rows. In general, this would rather be a matter of superstructure and hence an issue for the terminal operators. The increase in beam would mostly concern the North American West Coast ports as their Asian counterparts already handle larger ships on other trade lanes. A similar increase in ship beam is expected for intra-Asian trade, but this includes traffic between the major ports in the Middle East and the Far East. On the other major trade lanes, the cascade effect leads to roughly one row more. In scenario C, the first units with 20 rows may show up on Transatlantic trades while keeping the length ceiling of 370m. Still, almost all of the services will respect the New Panamax dimensions: 49 metres wide (19 rows) and 366 metres long (22 bays).

This illustrates that even if there would be no upsizing of container ships to 24,000 TEU ships, the dimensions of the largest ships calling the ports in almost all regions will change, due to cascading effects. This will imply adaptations of port equipment and infrastructure in these ports to be able to handle these larger ships. This will be even more pressing if 24,000 TEU container ships would be introduced in 2020, as this would further increase the dimensions of the ships, and thus the required infrastructure adaptations, although a more detailed study would be needed to gauge the exact extent of required changes.

Chapter 4. Mega-ships and peaks

Bigger ships lead to bigger peaks in ports. This is the result of decline of call frequency (less weekly services) and higher call size: more cargo loaded and unloaded per ship in the same port. This implies that the number of container moves increases with larger ships. This causes peaks at least three different stages of the cargo handling process: ship to shore handling, yard operations and for the interface between the yard and hinterland transport. This chapter analyses the peaks on these three elements of the supply chain, and concludes with a section on measures that might increase the potential to deal with these peaks.

Ship to shore peaks

The average ship turn-around time of world container ports was 1.03 days in 2014. The great majority of world ports manages to achieve average ship turn around lower than two days, most ports in Asia even lower than one day (Figure 4.1). The average ship turn-around time for ports in Japan is half a day, 0.7 days in South Korea and 0.8 days in China (Figure 4.2). European ports have relatively low ship turn-around times although less low than the Asian ports (Figure 4.3). Ports in Africa have generally longer ship turn-around times, where average turn-around times of more than three days are no exception; the port of Mombasa (Kenya) had an average turn-around time of 4.1 days in 2014.[5]

There has been an improvement of ship turn-around times in ports over the last decades. Using a similar dataset and methodology makes it possible to compare these turn-around times over time. The overall ship turn-around time in ports has slightly improved in 2014 when compared to 2011: from 1.05 days in 2011 to 1.03 days in 2014. This is part of a larger picture of more spectacular improvements in turn-around times between 1996 and 2006, in particular in China and other emerging economies (Ducruet et al. 2014).

Mega-ships generally stay approximately 20% longer in ports. Mega-ships are here defined as container ships with dead weight tonnage of at least 150,000, which translates roughly in container ships with TEU capacity larger than 13,300 TEU. In almost all of the ports where these ships call they take several hours longer than the ships below that threshold; in some ports these ships have turn-around times that are twice as long as the average, e.g. in Gdansk, Santos and Ambarli. There are only a few ports where the turn-around time for mega-ships is shorter than for the other ships; this is the case in Oakland, Algeciras and Khor Fakkan. There are various factors that could explain the longer port stay of large vessels, in particular their larger call size, which requires more moves. However, part of the

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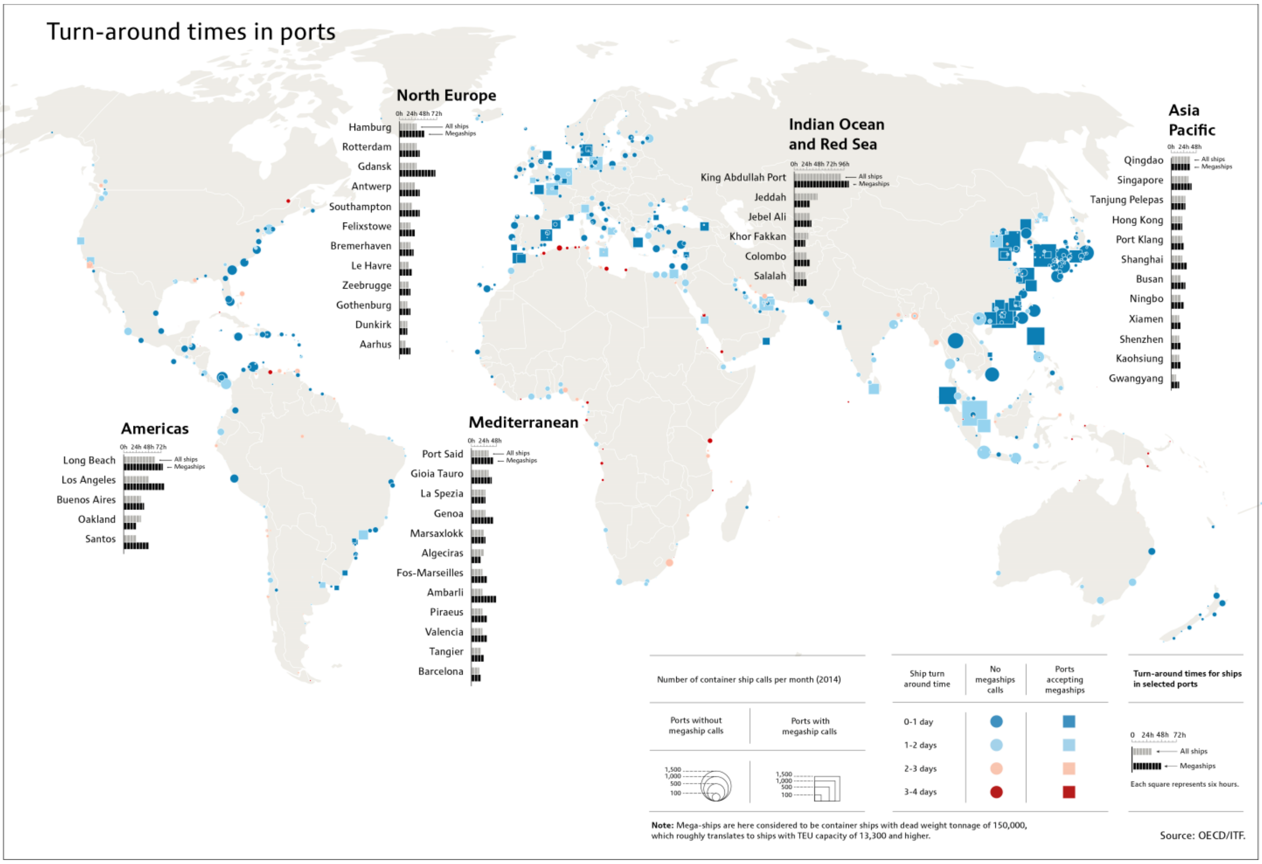
[5] These calculations are based on vessel movement data over May 2014 and May 2011 from Lloyds Intelligence Unit. The estimated coverage of this database is > 95% of all vessel movements. For the purpose of this analysis only fully cellular container ships with GT >100 were taken into account. The database has per vessel call an arrival time at berth and a departure time from berth, allowing for calculation of duration of port stays. For our analysis all port stays were excluded that were smaller than 0.20 days and longer than 7 days. In this way, bunkering calls and extreme values were excluded. The database that resulted included 38,843 port calls in May 2014 and 25,989 port calls in May 2011.

differences might also be explained by berth allocation policies: port and terminal operators can assign different priorities to calling vessels. For instance, at a terminal in China, small feeder ships have priority, as handling work associated with them is completed in a short period of time and larger vessels do not have to wait for a long time. On the other hand, a terminal in Singapore treats large vessels with higher priority because they are good customers to the terminal (Imai et al. 2013).

Figure 4.1. **Ship turn-around time of container ships in world container ports in 2014**

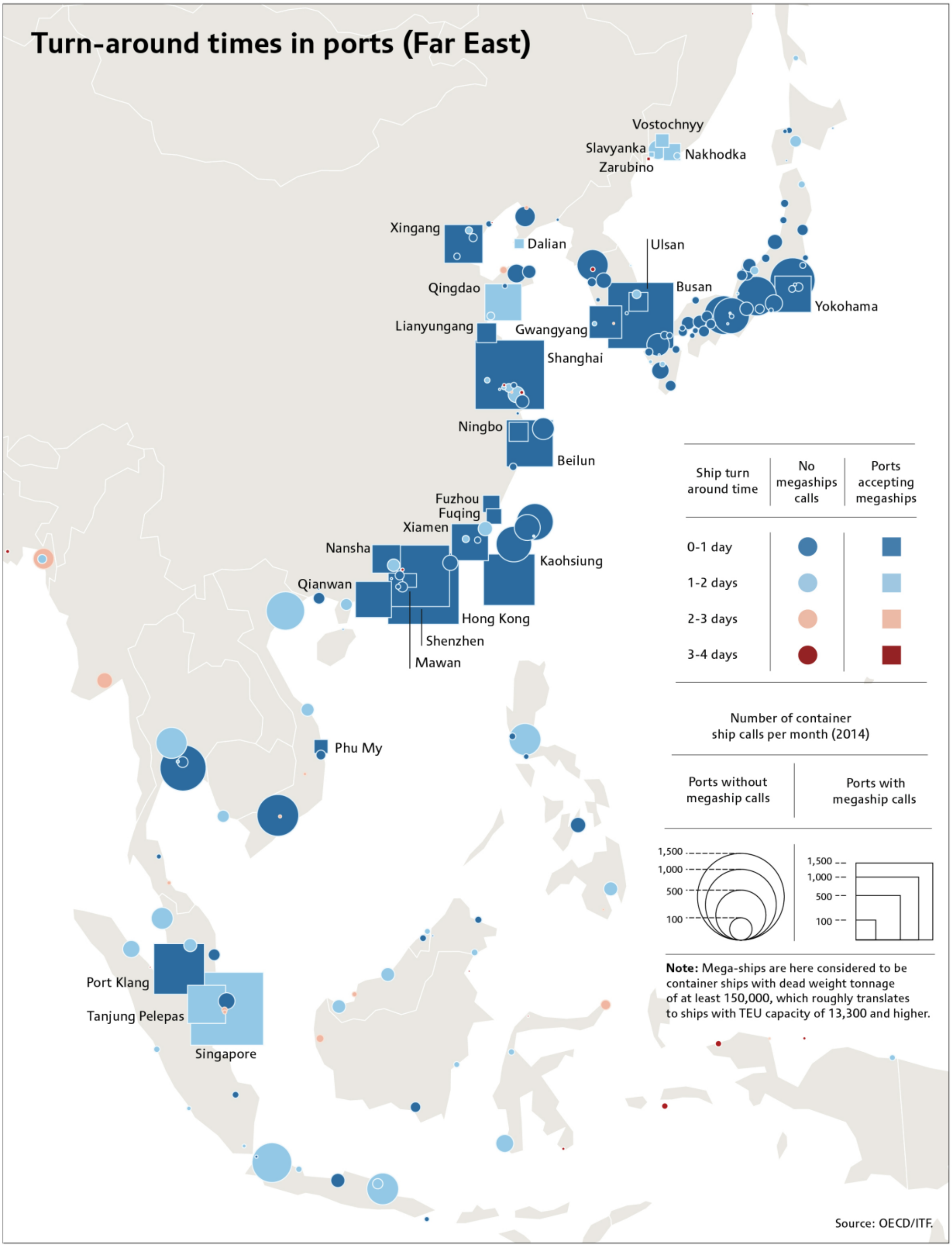


Note: Mega-ships are here considered to be container ships with dead weight tonnage of 150,000, which roughly translates to ships with TEU capacity of 13,300 and higher.

Source: OECD/ITF.

Source: Own elaborations based on data from Lloyds Intelligence Unit

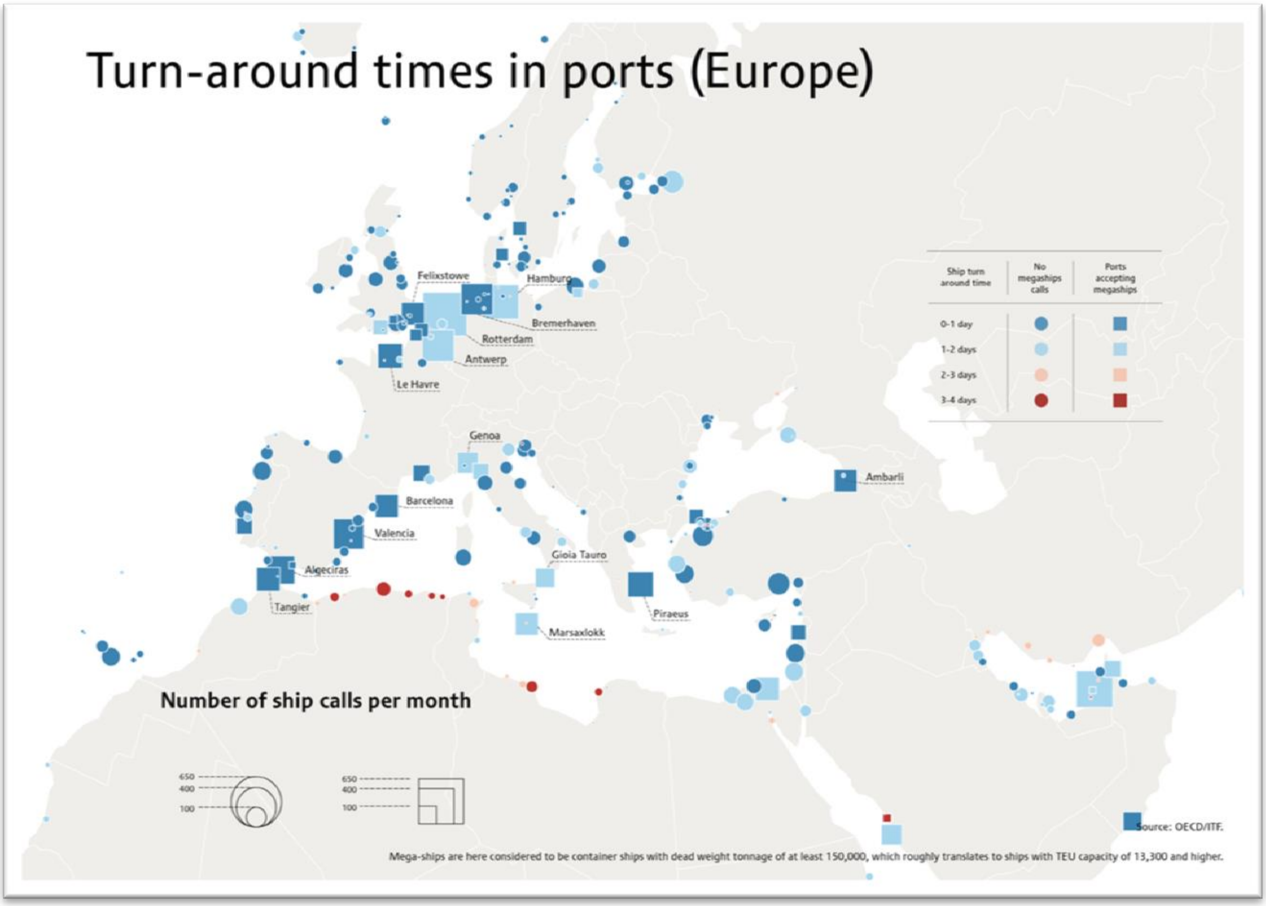
Figure 4.2. **Ship turn-around time of container ships in container ports in the Far East in 2014**



Note: Mega-ships are here considered to be container ships with dead weight tonnage of at least 150,000, which roughly translates to ships with TEU capacity of 13,300 and higher.

Source: OECD/ITF.

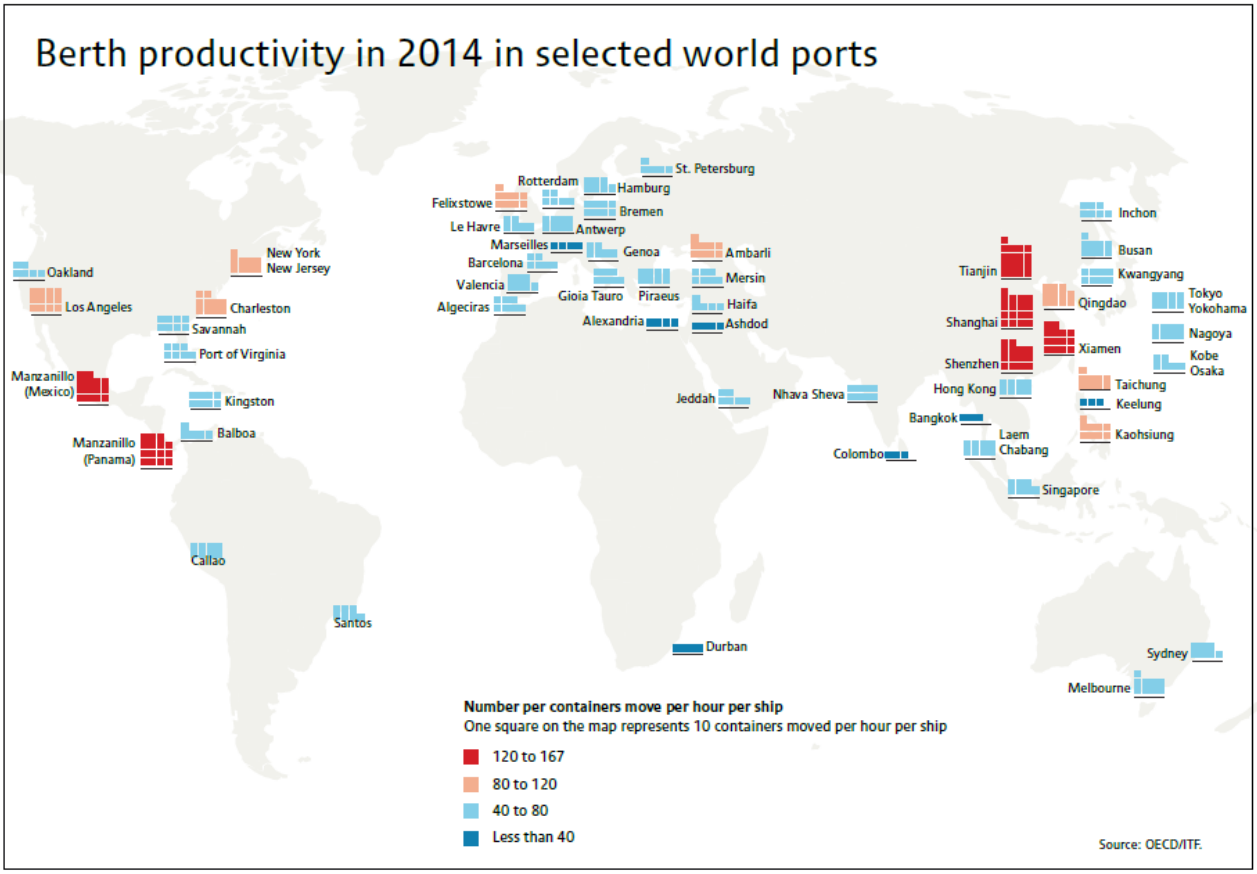
Figure 4.3. **Ship turn-around time of container ships in European ports in 2014**



Source: Own elaborations based on data from Lloyds Intelligence Unit

A more precise indicator of handling efficiency is the berth productivity at ports. Berth productivity indicates the number of box moves per hour that a ship is at berth. This has been calculated by relating ship turn-around times to TEU volumes realized in the same period. The results of this calculation for main world ports show a large variety of productivity levels, with a few trends that can be observed. The ports with the largest levels of berth productivity in 2014 were found to be the Chinese ports of Shanghai, Shenzhen, Tianjin and Xiamen; as well as Balboa (Panama) and Manzanillo (Mexico). According to our calculations, the highest berth productivity in 2014 was reached in Shanghai, with approximately 164 box moves per ship per berth hour (Figure 4.4). Low productivity levels were recorded in the ports of Colombo, Bangkok and Keelung. A more detailed study would be needed to understand what can explain the differences in berth productivity between these ports. In general, there are two ways through which the ship turn-around time can be improved: via higher crane density (more cranes working the ship) or higher crane productivity. The paragraphs below assess the challenges related to these.

Figure 4.4. **Berth productivity in main ports in 2014**



Source: own elaboration based on databases from Lloyd's Intelligence Unit and ISL

Mega-ships: need for more cranes?

There are limits to increasing crane density. Since 1975, the workload required by terminals to service container ships has risen by 709%, the average workload performed by each crane has increased 382%, but the number of quay cranes deployed to work a ship has increased by only 87% (Martin *et al.* 2015). Whilst terminal operators have been able to deploy additional cranes they have at the same time had to increase the utilization and performance of individual quay cranes by nearly fourfold. To achieve this terminals have either increased the proportion of time each quay crane is working whilst a ship is in the port, or have increased the number of moves each crane performs per hour. The ship-to-shore workload has become increasingly concentrated as the length-beam ratio has reduced (Martin *et al.* 2015).

Ship-to-shore operations are further affected by the stowage distribution of containers for each port of call between the bays of the ship. This distribution acts as a constraint on the number of quay cranes a terminal can deploy to work the ship, and is known as the crane split (Bierwirth and Meisel, 2010). As the number of port calls within a rotation increases, so does the complexity of ship stowage and the more difficult it becomes to distribute containers along a ship to optimise the number of quay cranes that can effectively work the ship (Gilman, 1975). Containers for individual port calls become more concentrated in a few bays with small pockets of containers for each port located in other bays. This has the effect of limiting the number of quay cranes that can be deployed, leading to poor crane split, and one crane having a disproportionate amount of work extending the time required to work the ship.

Quay cranes are necessarily wider than the width of a bay block. Consequently when working a bay, a quay crane will block access to the bays on either side and prevent them from being worked by other cranes; this is known as the adjacent bay constraint (Murty et al. 2005). For example for Maersk's E-class ship, when applying the adjacent bay constraint, it is only possible for seven cranes to simultaneously work the forward section and five the stern at any point in time, setting the maximum upper limit of twelve quay cranes for this class of ship. The CMA CGM's 16,000 TEU Marco Polo ship and Maersk Triple E have the bridge and engines in different locations, giving an upper limit of thirteen cranes.

The effectiveness of increasing crane intensity is also constrained by the number of traffic lanes one can fit under the crane. For example, it could be considered optimal to have seven lanes for seven trucks passing underneath seven cranes working a vessel; otherwise a truck needing to reach a crane further downstream in traffic flow terms might be impeded by other trucks already queuing waiting for upstream crane service. Although there are ways around this, the simplicity and optimality of the system is lost with more cranes that are generally not wide enough to have more lanes passing underneath them.

However, it would be possible to deploy more cranes on mega-ships than is currently done. Cullinane and Khanna (1999) showed that for the largest container ship at that time, the 7,400 TEU Maersk K class, with a maximum of 10 deployable quay cranes, there would be on average 5 deployed. They observed that at the end of the process of working a ship a single crane would be used to complete the ship. When this factor was included the actual average number of quay cranes used to work the K Class was estimated to be 4.4. The average number of quay cranes deployed was less than half the maximum that the ship design allowed, according to studies by Maggs (1978) and Cullinane and Khanna (1999). For ships capable of accommodating 12 quay cranes a maximum of eight cranes would typically be used with an average of 5.5 cranes per ship working time, according to Martin *et al*. 2015. Sometimes, these high crane deployment numbers are reached, but this is exceptional to such a point that shipping lines and terminal operators make press releases about it, e.g. the CMA CGM ship worked with 12 cranes by Gulftainer.

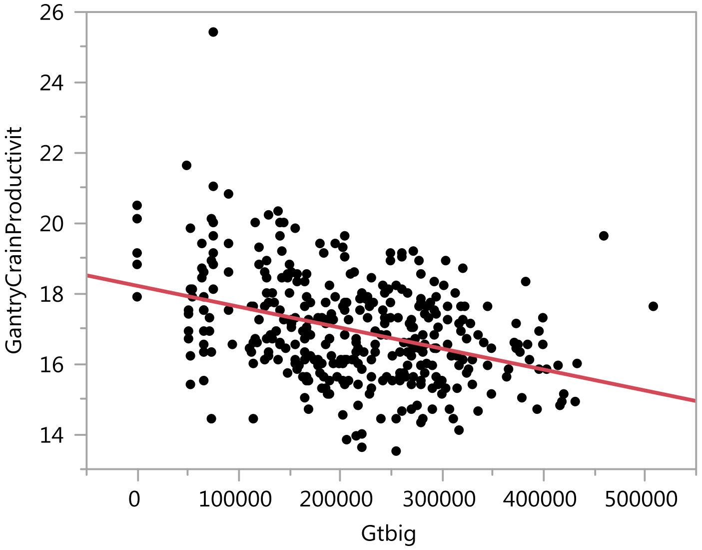
Need for higher crane productivity?

Generally, larger ships tend to reduce crane productivity. Bigger ship dimensions mean longer working cycles for each container handled by a quay crane, which in turn will have a significant effect on quay crane productivity. Quay crane productivity is measured by how many cycles or container moves it is able to perform per hour. A typical quay crane cycle consists of the spreader moving to a ship location, picking a container, hoisting the container back to the wharf and setting the container down. For a larger ship, the spreader would need to traverse a further distance to access containers on the far side and would also have to travel further down in the ship hold (Le, 2013).

Simulation studies show that for a very skilled operator working to just single picks, the maximum productivity could be as high as 40 moves an hour for the New Panamax, and more than 45 moves per hour for a Panamax ship. This productivity drops to scores in the thirties as the pick and set times increase. The period it took in this simulation to move the container across the vessel after picking and before setting it down is about 52 seconds for the Panamax ship and 64 seconds with the New-Panamax ship. On average, for single moves, the difference in productivity between vessel size appeared to be about five moves per hour per quay crane (Le, 2013). Big ships are more sensitive to crane speed because they have more distance to cover. For example, with an increase in hoist speeds from 90 metres per minute to 135 metres per minute, the New-Panamax showed a three- to five-percent increase in productivity as opposed to a one- to one and a half percent increase with the Panamax.

These effects were confirmed in other studies. Rudolf (2010) observed that the operator is subject to some degradation of productivity with longer cranes, because of the longer spreader hang length, which results in a longer swing period and also because of difficulties to see depth. These effects were estimated in this study at 2.5 seconds on each end of the cycle. He concludes that investment in more modern (faster) can overcome the disadvantages that a dimensionally larger crane would impose on the operator. According to his study, cranes that can tandem forty foot lifts – in comparison to single or twin twenty lift cranes - make economic sense to terminal operators if the operator can make such lifts on at least 30% of the moves (Rudolf, 2010). Our own analysis also shows that days with mega-ships (as measured by the total GT of big ships on the same day) show lower gantry crane productivity rates, both with respect to average rates as maximum rates (Figure4.5).

Figure 4.5. **Relation between total ship volume (GT) calling a port and crane productivity per hour**

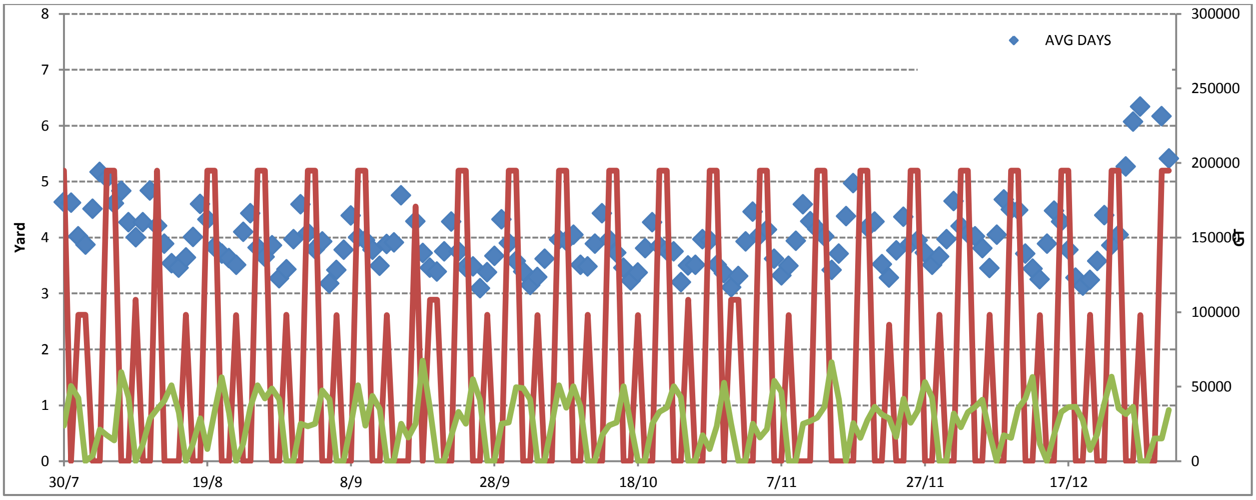


Source: own elaborations based on terminal data

Peaks in yard operations

There is a clear link between dwell time in container yards with ship size, due to the peaks mega-ships generate. This can be most clearly shown in ports with only one weekly mega-call, where the dwell time is highly correlated (Figure 4.6), as well as the predictability of the yard occupancy (Annex 1). There are two possibilities to solve peaks in yards related to mega-ships: increasing yard density and reducing dwell time. Yard density can be increased by stacking higher. This is dependent on choice of equipment (straddle carriers or rail mounted gantry cranes) and panning. Dwell times depends on administrative procedures, controls etc, but also on where warehouses are (close to port etc), inland container depots, dry ports etc.

Figure 4.6. **Relation between yard dwell times and mega-ship arrival**



Source: own elaborations based on terminal data

Mega-ships need more flexible labour

Labour is an important production factor for port terminals, since labour costs in container terminals could account for more than half of their operating costs (Barton and Turnbull, 2002; van Hooydonk, 2013). This translates into considerable labour costs per goods shipped. The average labour cost is close to USD 200 per container shipped into Los Angeles. Containerisation has facilitated the enhanced accuracy of ship sailing schedules, reducing the irregularity and unpredictability of employment, which was for a long time the fundamental challenge of port labour markets (Haralambides, 1995). Demand for port workers has in many container ports become relatively stable and predictable. The irregularity of demand is solved by overtime and extra shifts, but also by casual workers who supplement the core workforce; the casual workers may be port pool workers, workers temporarily hired out by other cargo handling companies, workers supplied by sub-contractors, temporary agency workers or occasional workers. In most cases, casually employed workers have no income guarantees (van Hooydonk, 2013).

Whereas containerisation has regularized port labour, mega-ships require more flexibility. More peaks mean more flexible labour, so more flexible labour time and labour pools or other mechanisms, probably resulting in more labour costs. In addition, mega-ships require more 24h operations, which is not the current mode of operation of many port stakeholders, including customs and other inspectorates in ports. For instance at HHLA terminals in Hamburg, customs office hours are operated at night, but only from Monday morning to Saturday afternoon, stopping the operations for more than 30 hours.

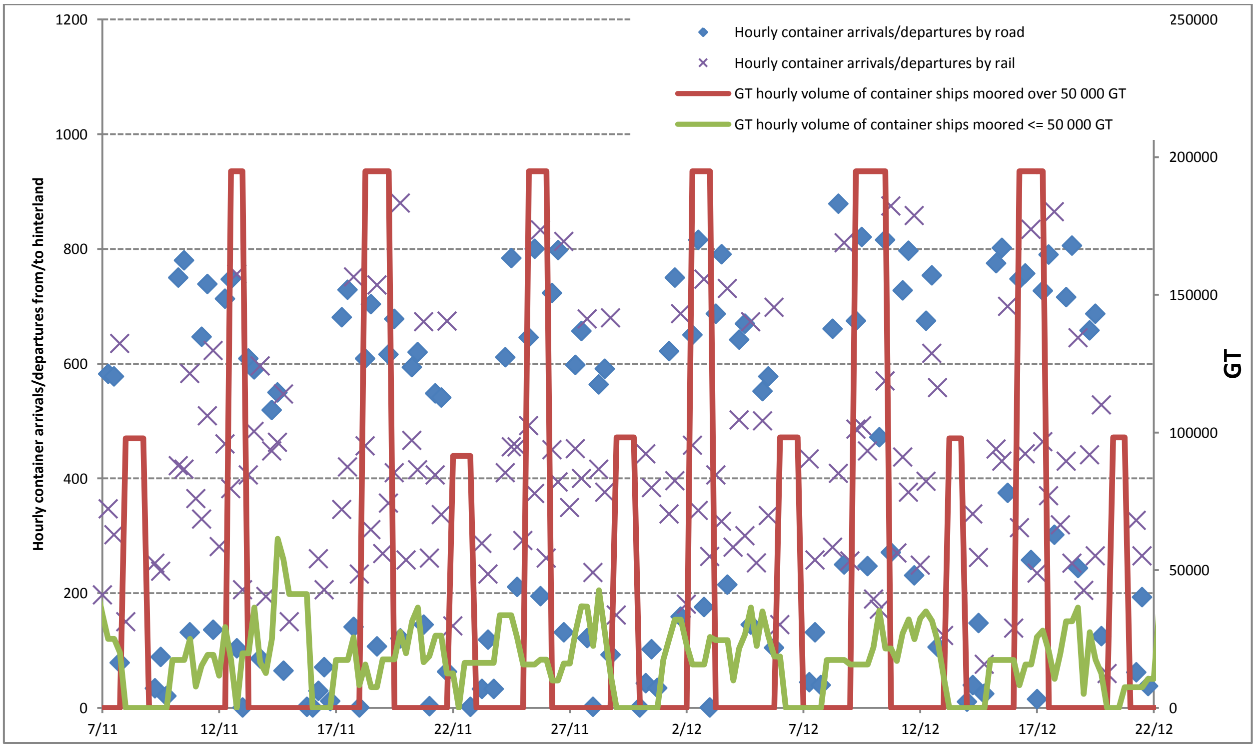
Logistics in general is even more restricted in time as a number of work and traffic regulations generally impose warehouses to close or trucks to stop driving at given times. Warehouses of shippers are generally closed at night or at weekends with the last shipments leaving in the evening. A pilot experiment was conducted with a coffee trading company located in the Hamburg region to determine what would happen if truck movements from port to warehouse were also conducted at night time. The company had its own warehouse and trucks, which enabled it to operate the entire loop and to adapt the opening times of the warehouse to the arrival times of the truck. Results showed that the number of trips more than doubled. This illustrates the potential benefit to gain from implementing similar initiatives for the whole transport chain, reducing congestion and transport costs.

Another issue in this regard in the existence of regulations on truck traffic in various European countries, or locally. For instance, Germany does not allow goods vehicles over 3.5 tons carrying trailers on roads during weekends and public holidays between 00:00 and 22:00. Similar measures are also implemented in France on Sundays and before public holidays. However, an exemption from the weekend truck prohibitions is for combined transport (truck-rail or truck-sea) within a certain area around Hamburg despite the strong enforcement of the rule all over the country, which shows that fluid and constant traffic is essential.

Peaks related to hinterland

The arrival of mega-ships in a port creates peaks in terms of hinterland traffic in gateway ports. This is illustrated by Figure 4.7, which charts the arrival of mega-ships, regular ships, trucks and train movements in a port with one weekly container mega-ship call.

Figure 4.7. **Relation between mega-ship arrivals and port truck movements**



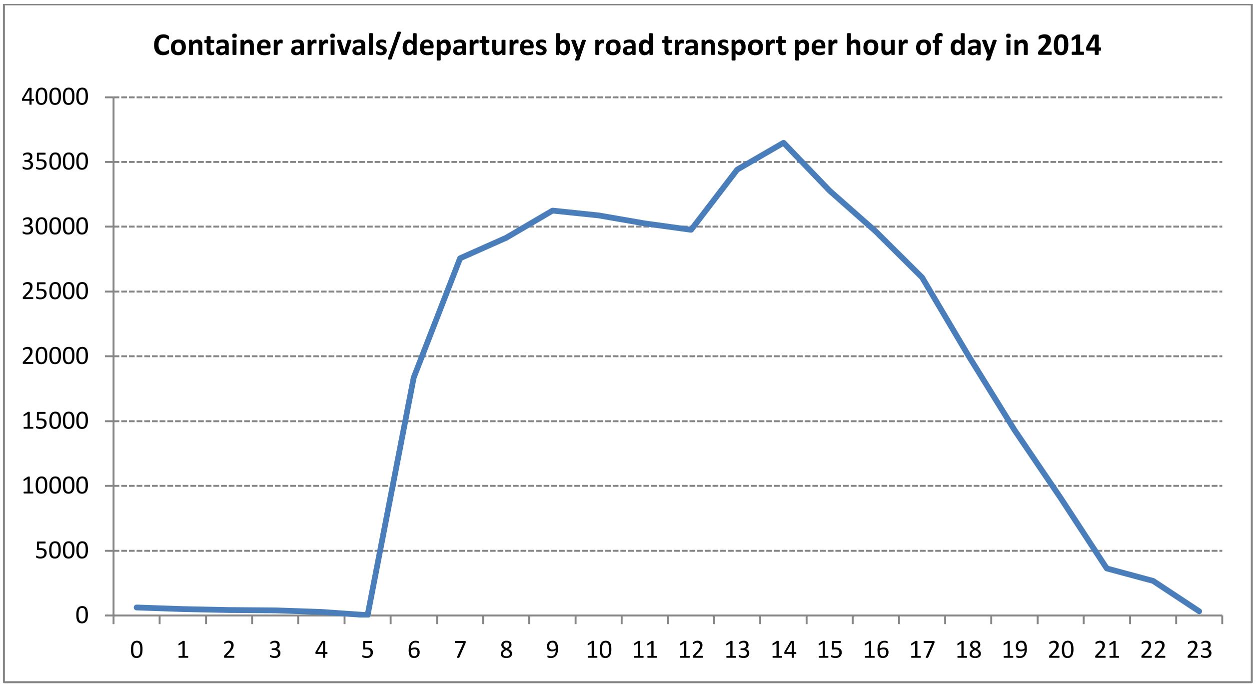
Source: OECD/ITF elaboration based on data provided by port authority and terminal operator

The impact of the mega-ships on the port hinterland connections differs depending on the ship type. The freight volumes of a Ro/Ro-ship are on the hinterland network immediately before or after the ship call. The volumes of other types (container, car-carriers, break-bulk) tend to be spread out in time more evenly and create lower peaks. With the mega-ship call frequency increasing, the peak pattern that is shown in Figure 4.7 will turn into a continuously high traffic level on the hinterland transport modes. This could be advantageous for the hinterland transport modes, because an appropriate level of investment could be provided for rolling stock and infrastructure for a high demand without the peaks.

Mega-ships create certain capacity requirements for hinterland connections. The road hinterland connections should be able to handle the high cargo volumes that enter and leave the port in short periods of time before, during or after the mega-ship call. Therefore certain road access improvements would usually be necessary in relation to those peaks. Infrastructure improvements could be needed also for the rail and barge connections, because the large cargo volumes of mega-ships allow having the required capacities for operating rail shuttles and barges profitably.

The peak traffic of trucks related to the arrival of mega-ships could also contribute to urban congestion. However, much depends on the local situation and geographical layout of the port in relation to the city. Figure 4.8 depicts the distribution of port truck movements over the day in one particular large port in Europe, showing traffic to peak in the early afternoon steeply declining until the evening. In this situation, urban traffic and port traffic have different peak times, so port traffic only contributes to a limited extent to urban congestion levels. However, there are cities where the distribution of port traffic over the day is different, with more significant impacts on urban congestion. There is also no truck activity during the night, which is common in many ports. This allows potential solutions to be developed and introduced for easing port truck traffic if this were needed. The possible measures for doing this could include incentives to cargo owners and truckers for off-peak deliveries.

Figure 4.8. **Distribution of port truck movements over the day in a selected port**



Source: OECD/ITF elaboration based on data provided by port authority and terminal operator

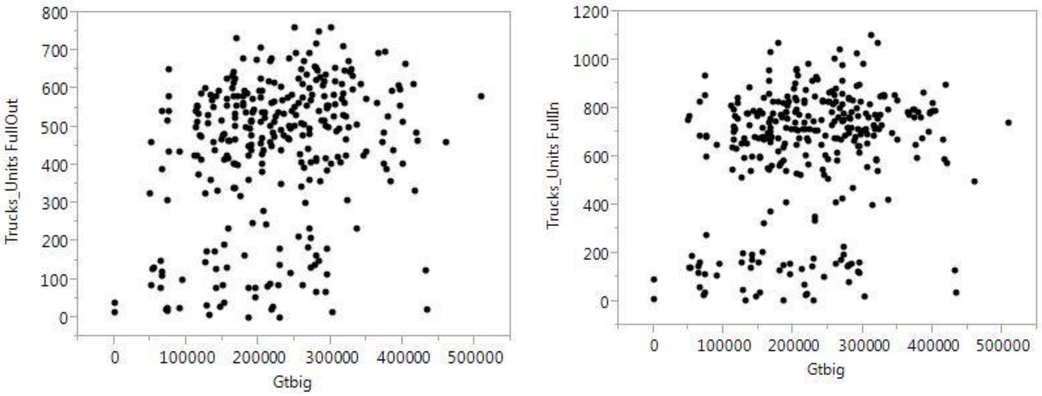
Mega-ships might intensify the need for better port gate planning. This is particularly the case for gateway ports, which have a lot of land hinterland traffic. Better port gate planning could take the form of truck appointment systems and promote more off-peak hour operations, which could be stimulated by instruments like the Pier Pass in the ports of Los Angeles and Long Beach. Operating during night time is a challenge in many ports, also because many warehouses and logistics centres related to ports are generally closed at night. The peaks related to mega-ships could increase the necessity for 24 hour operations, in order to increase the throughput of the container yard with the free capacity in the off-peak hours of the day. Various port terminals are open at night, but this is often not the case for customs and other bodies.

Mega-ships also increase the need for a more fluid synchronization of ship movements and hinterland transport movements, be it trucks, trains or barges. So it requires more sophisticated information systems that integrate data from the different transport modes. Such a holistic information system would also allow for implementation of what has been labeled “synchro-modality”.

Opportunities for modal shifts

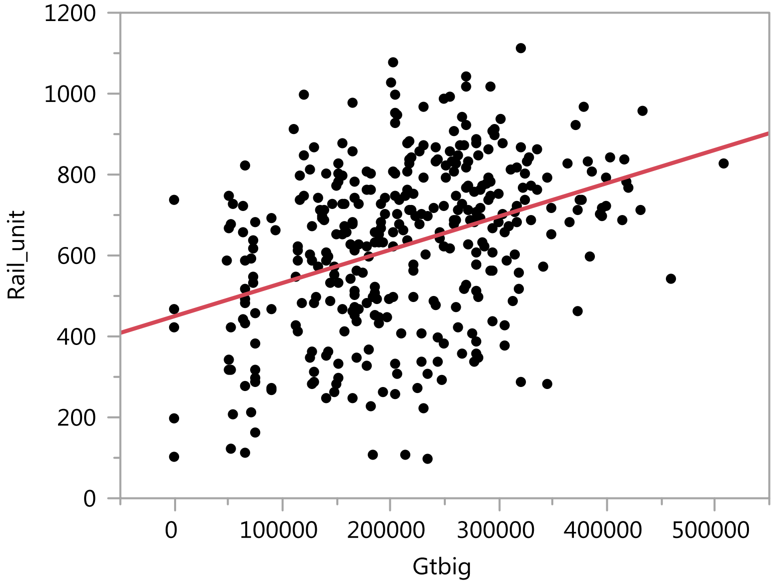
A typical mega-ship call is associated with a large volume of cargo that has to arrive or leave the port. This could provide opportunities for modal shift from trucks to rail or inland waterway transport, considering the volumes that can be consolidated. This can be illustrated by data of truck and train movements of a certain port terminal that were in relation to the ship size. If we look at the incoming containers and outgoing container flows by road in Figure 4.9, it is clear that the ship size does not cause an increase of the road freight traffic. However, the Figure 4.10 for the same port shows that the number of containers transported by rail increase as the ship size increases. More volume does not always present opportunities for modal shifts. In many countries the potential of the barge system to absorb larger volumes seems to be hampered by fragmentation of the sector.

Figure 4.9. **Link between ship size per day and road hinterland transport flows**



Source: Own elaborations

Figure 4.10. **Link between ship size per day and rail hinterland transport flows**



Source: Own elaborations

However, there are many challenges in practice that would need to be solved, including sufficient rail access to ports, a sufficiently liberalized freight rail market and enough capacity on the railway network to deal with freight trains. Similarly, for the inland waterways sufficient waterway infrastructure with appropriate depth, locks and bridge height should be provided to deal with the traffic volumes. Mega-ships might increase the need for more dry ports and extended gate development. This would allow cargo to/from a port to continue its voyage without taking up space in the port area and avoid congestion on the port access roads.

Box 1. Smart Port Hamburg for smart logistics and intermodality

Hamburg Port Authority (HPA) is conscious of the pressure ever larger ships put on the port's infrastructures and actors. To answer the problem best, it created the programme Smart Port Hamburg with the idea to optimise the existing capacity of the port by inviting all port actors to collaborate. It encourages them to share their data to develop IT tools dedicated to facilitating time conflict resolution and efficiency at the port. As part of this effort, HPA is developing an Intermodal Port Center to produce and make available traffic data in other to smoothen traffic at the port. Several tools are being created:

- Effective Depiction of the Traffic Situation (EVE): One system merging data from existing measuring points to efficiently represent real time traffic but also to gather data on short and medium term traffic situation. Information collected ranges from travelling times, to CO_2 consumption to time spent in traffic jams. This will enable to offer data evaluation and short-term traffic forecasts but will also help developing other indicators and tools to improve efficiency at the port. The idea is also to increase the number of measuring points as well so as to make the system as comprehensive as possible.
- Port Road Management Center: To better distribute traffic within the road network through an IT support of all road areas (incident management, car park management, real-time traffic information, traffic management before but also on terminal approach with pre-gate parking, etc.)
- Parking Space Management: A tool to optimise the use of actual and future parking spaces dedicated to trucks in order to help them not to park in residential areas. It will work through parking area detection and administration to provide information about spaces available.

- The SmartPORT Logistics App: Mobile and computer tool developed by HPA for the use of all actors creating traffic at the port. It will serve as a traffic and information platform delivering personalised information to its users about the traffic situation at and around the port, about infrastructure restrictions and closing times, about the situation at the container yard and at the parking facilities and include a booking system.

Do mega-peaks require a productivity revolution?

The evolution of ship size has important repercussions on the productivity of port terminals. Shipping lines expect that as their productivity rises, terminal operators manage to increase their efficiency while adapting to the new constraints imposed by their ships. Up to now, container handling equipment technologies have managed to adapt to larger vessel height and length and to increasing numbers of moves per call, not without considerable investments, but as ships grow faster than they used to, a revolution on in terminal productivity might be needed in the coming years.

Cranes have become bigger and faster over time. They have grown considerably in size and height. The largest ones now have an outreach up to 70 meters with enables to grab containers up to 25 rows. Their height can reach 80 meters with a lifting height capacity above quay up to over 50 meters and 20 meter below. They also went from single hoist able to handle one 40 feet container or two 20 feet containers to tandem arrangements (single hoist tandem or double hoist tandem) that enabled to double this capacity. The largest container quayside crane on the market, developed by Zhenhua Port Machinery Corporation has recorded a productivity of up to 123.16 moves per hour (ZPMC).

As ship capacity has increased over the last few years, ship length has remained fairly similar. The difference occurred mostly thanks to larger ship beam and higher stacking heights. While longer ships would have enabled the positioning of other cranes to handle them, increased width and height are major challenges for cranes technologies that need to have an ever longer outreach and height. As moves per ship also increase with ship capacity, there is pressure on the speed of loading and unloading operations. Berth productivity is constrained by at least two issues: 1) ships are worked from only one side, and 2) there is the adjacent bay constraint (a quay crane will block access to the bays on either side and prevent them from being worked by other cranes). The following solutions have been proposed for these constraints:

1) Working the ship from both sides. An example is the indented berth-concept developed by the Ceres Terminal in Amsterdam at the beginning of the 2000s. This terminal had a slit enabling ships calling there to dispose of cranes from both sides, so as to greatly maximize berth productivity. This concept allowed nine cranes to operate the ship at the same time, which could result in a berth productivity of 300 moves per hour.

2) Solving the adjacent bay constraint. New crane concepts provide potential to improve productivity. An often cited example is the Fastnet crane, developed by APM Terminals. It consists of individual cranes mounted on a single elevated grider supported by very large automated pillars moveable on rail which eliminates the constraints imposed by the width of today’s cranes. They are controlled by a system that will ensure that each crane will always be able to reach all the bays of the ship. Extensive computer simulations have shown that berth productivity could be doubled using when such a system for large call sizes.

Various solutions are also proposed to move more efficiently containers from a point to the other by using waterways instead of using terminals. These can take the shape of offshore terminals, new ways of moving containers around within and outside terminals, and new ways of transshipping containers. Examples include: barges equipped with cranes to operate as a shuttle between ports terminals, barges that use Archimedes' principle and compressed-air technology to travel between the offshore and onshore terminals. Other concepts have been looking at the way floating structures could become alternative to land based terminals, in large part to avoid the cost of reclaiming land and building new quay walls.

Who drives terminal productivity innovation?

The push for port terminal productivity seems currently to be mainly driven by equipment manufacturers. This at least what could be concluded from an analysis of patent applications related to port terminal productivity. Patent applications can give some impression of which actors are driving the port terminal productivity innovation. For this study the patent applications were assessed in the relevant patent classification categories related to port terminal productivity (Annex 4). It turns out that many patents in this area are registered by port equipment manufacturers, such as Gottwald, Paceco Corp, Noell Mobile Systems, Mitsubishi, Siemens and Zhenhua Port Machinery Group (Table 4.1). Our assessment also showed that various terminal operators, such as APM Terminals and PSA, filed some patent applications, as well as shipping lines (Maersk and NYK). However, the great majority of patent applications remain attributed to individuals which could hide applications from companies that do not disclose them for competition reasons.

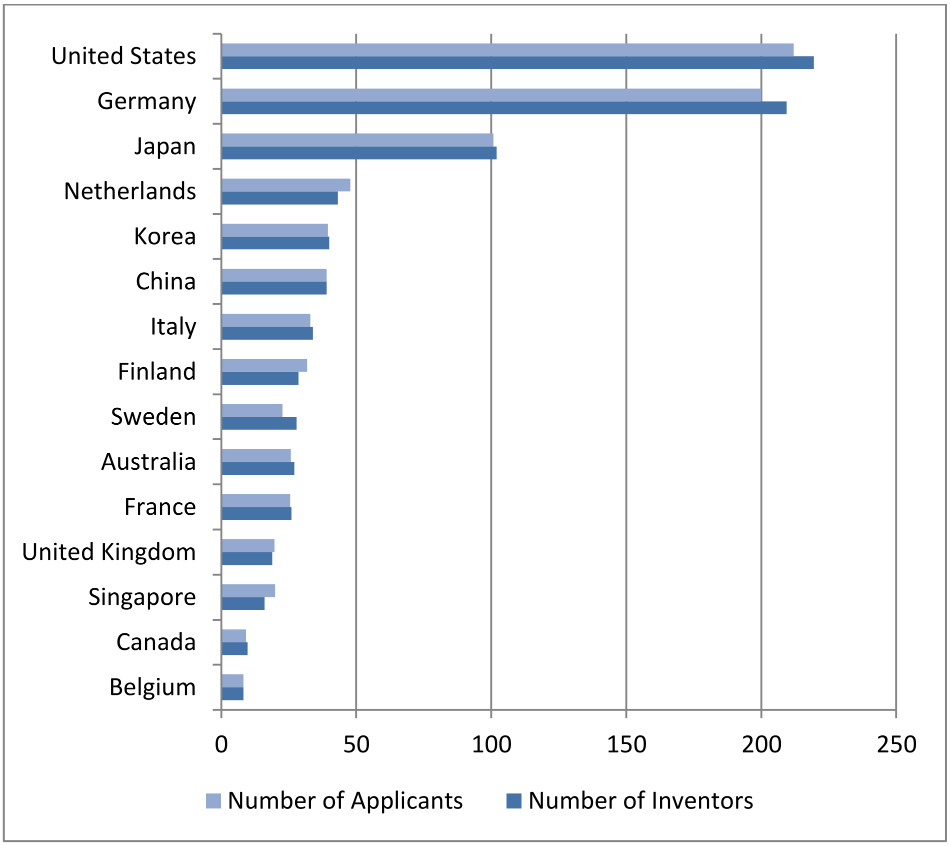
Table 4.1 **Which companies have the most patent applications related to port terminal productivity?**

Name / Group	Country	Number of patents
Gottwald	Germany	33,76
Paceco Corp	US	26,96
Noell Mobile Systems	Germany	23,16
Mitsubishi	Japan	21,66
Siemens	Germany	18,61
Zhenhua Port Machinery Group LTZ	China	16,25
Cargotec (includes Kalmar)	Finland, Netherlands	12,28
Konecranes	Finland	10,33
AP Moller Maersk AS (Includes Maersk + APMT)	Various	10,16

Source: Own elaborations based on data from OECD Patent Database

The top five countries for producing and filing these patents are the United States, Germany, Japan the Netherlands and Korea (Figure 4.11). Together these countries were responsible for well over half of all the patents filed between 2000 and 2012. The United States and Germany lead the way with respectively 212 and 200 applications between 2000 and 2012. Japan follows with less than half (101 applications) the numbers of the first two. The Netherlands and Korea are also close together with less than half the Japanese patent production (respectively 48 and 40 applications). China follows the top five with 39 applications.

Figure 4.11 **Which countries have the most patent applications related to port terminal productivity?**



Source: Own elaborations based on data from OECD Patent Database

Chapter 5. Mega-ships and the transport chain

The main beneficiaries of mega-ships are supposed to be the container shipping lines, but mega-ships have fuelled ship overcapacity that has depressed freight rates and profit margins of shipping lines. In this indirect way, mega-ships have contributed to lower maritime transport costs that might have benefitted shippers and consumers. New mega-containerships are greener than older ships, so there are certain positive external effects related to these, but these are arguably more connected to new ship design features rather than economies of scale per se. At the same time, there are costs that mega-ships impose on the rest of the transport chain.

This chapter takes the elements from the previous chapters together to estimate the costs for the transport chain that are related to the introduction of mega-ships. On the basis of this calculation various policy measures are discussed. These policy measures include the alignment of incentives to public interests, collaboration, regulation and governance of the supply chain.

Costs imposed on the whole transport chain

The notion that larger ships result in larger costs for the whole transport chain is not new, but calculations of these costs are rare. Various academic studies going back as far as the 1980s have postulated economies of scale for maritime transport, and diseconomies of scale for the handling and transport related to this (e.g. Jansson and Sheerson 1982; Cullinane and Khanna, 1999, 2000; Sys et al. 2008; Malchow 2014; ISL 2014). Only a few have managed to estimate costs related to the increasing size of containerships. A recent example is Saanen (2013), who indicates that the upsizing to larger containerships leads to higher terminal costs, with operational costs rising with 17% when going from a scenario with 4,000 TEU ships to one with 18,000 TEU ships. However, one can observe that no calculations seem to exist that take all the different elements of the transport costs into account, not only terminal operation costs, but also costs related to maritime access (dredging), port infrastructure (quay, yard) and port hinterland transport.

Such calculations are rare, because these are complex and delicate. This complexity has different causes. First, it is difficult to isolate the effect of the upsizing of container ships without becoming somewhat detached from reality. Second, there is local context that implies different costs for different ports: transshipment ports have less hinterland related costs, river ports will have more dredging costs, dredging costs differ according to soil types – and many more local specificities can impact on the relevant costs. Finally, there are commercial interests that make it difficult to get insights into details of costs of port operations, because are considered to be sensitive considering the competitive environment they are in. The interplay of these factors makes calculation of transport costs related to mega-ships a challenging exercise. So it is with many reserves and caveats that we present our calculations; these should be considered a first preliminary exercise, based on a thought experiment, with various assumptions that could be challenged.

Our rough preliminary calculations suggest that the transport costs related to the newest mega-ships could amount to approximately US$ 0.4 billion. This finding is the result of a calculation on the possible effects of deployment of 72 19,000 TEU ships (20 already in operation, 52 currently in the order books) instead of deployment of 98 14,000 TEU ships. In order to isolate the effects of this, we ignore existing port capacity and other ships larger than 14,000 TEU.[6] The main impacts from the deployment of these different ships are with respect to dimensions, peaks and berth productivity. The 19,000 ships are longer, wider and deeper, which has consequences for the required quay length, crane height and outreach and depth of berth and access channel. Larger ships have larger port call sizes, which means larger peaks, which have an impact on port hinterland transport. Finally, a similar amount of port days is assumed for voyages from 14,000 TEU ships and 19,000 TEU ships, which is in line with the calculations conducted to establish cost savings of 19,000 TEU ships in comparison with 14,000 TEU ships, and also in line with current practice. This implies that higher berth productivity is required for 19,000 TEU ships; considering that crane productivity is more or less fixed in the short term, the main way to achieve higher berth productivity is the deployment of more cranes, and consequently more yard equipment, in order to avoid terminal congestion. For all the elements indicated here, standard unit prices and depreciation periods have been defined, based on a variety of sources, including from actors in the industry. A more detailed description of the methodology and assumptions underlying the calculation of the transport costs related to mega-ships can be found in Annex 5.

Our first findings seem to indicate that roughly a third of the additional costs is related to equipment, a third to dredging and another third to port infrastructure and port hinterland costs. The equipment-related costs are mostly driven by the higher berth productivity requirements that are assumed. The dredging costs are caused by the larger draft of the 19,000 TEU ships, which requires deepening of the access to the port, which can generate substantial costs, especially for river ports. Finally, there are costs related to port infrastructure (quay and yard) and port hinterland. Although large, the investments in quays can amortised over a long time period, whereas yard extensions might be challenging due to land constraints in various ports. With respect to port hinterland connectivity related to mega-ships, additional rail links needed, but these investments are also supposed to last long, so the costs could be spread out over time. We assume that the higher peaks lead to more truck traffic to and from the port, which will aggravate urban congestion during peak hours; this means time loss to trucks, which can be translated into a monetary value.

These costs not only occur in ports where these mega-ships call, but also in many other ports, because of cascading effects. E.g. the calculated additional costs for the six relevant North European ports are calculated to be approximately US$ 75 million per year; for the nine Far East ports this is approximately US$ 85 million per year. We assume that, due to cascading effects, there will also be adjustment and adaptation costs in ports in the Mediterranean, in the Americas, in the Middle East and Oceania.

Who bears the costs?

Different transport actors each carry part of the transport costs imposed by the mega-ships. In most cases equipment costs are covered by terminal operators, dredging costs by port authorities or other public bodies and hinterland infrastructure improvements by governments. In practice, there are various hybrid models, also depending on the port governance models in countries, ranging from totally privatized ports (fairly rare), to public port authorities with private port operations (most common) and completely public ports (where both port authority functions and port operations are in public hands).

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[6] The reason to compare the current mega-ships of 19,000 TEU with those of 14,000 TEU, is that the introduction of the Triple E-ships with almost similar dimensions to the previous generation of containerships of 15,500 TEU has made these last ships no longer an attractive option for carriers, which can be illustrated by the fact that ships between 15-17,000 TEU are no longer ordered.

The same remarks with regards to hybrid models apply to some of the other cost categories taken into account in our calculations, such as quays and yard space. Congestion costs related to peaks are mostly covered by the transport companies active in hinterland transport to and from the port, such as trucking companies, barge companies and railway companies.

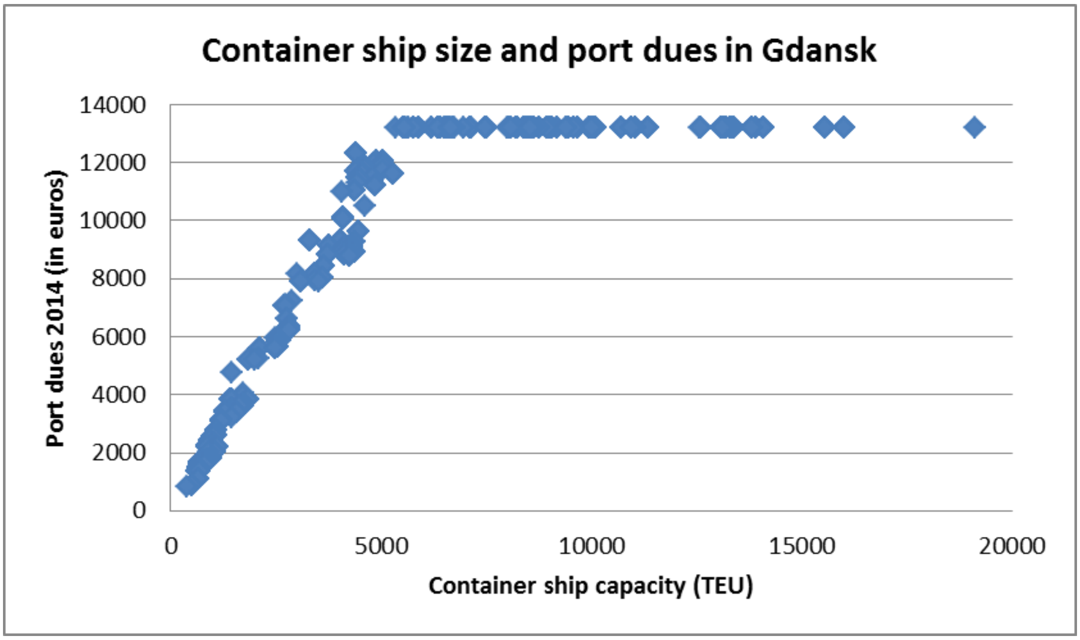
Alignment of incentives to public interests

Current incentives to attract mega-ships

An additional element to take into account is the extent to which current mechanisms stimulate mega-ships. An example is the incentives generated by port tariffs. With most port authorities over the world moving towards a landlord model, their main policy instruments are now within the field of concession agreements and port tariffs, in addition to whatever regulatory powers they might have. Port tariffs are tools that port authorities can use to attract certain types of ships and cargo, by cross-subsidizing these at the cost of other ship types and cargo. E.g. certain ports are using port tariffs to promote greener ships. In similar vein, port tariffs can also be tools to attract very large ships.

Our first assessment of the structure of port tariffs of world ports indicates that various ports have tariff structures that favour large ships. An example of this is the port of Gdansk in Poland, that has a port tariff that is capped for all ships larger than 60,000 GT, which results in a situation where total port dues for 5,000 TEU ships are the same as for 19,000 ships (Figure 5.1). Similar examples of mega-ship-favorable port dues can be found in other ports, although many ports have a fairly proportional approach which works out fairly neutrally for ship size. A common tariff structure is one tariff per gross tonnage of a ship, e.g. in Singapore, which means that port dues are more or less proportional to TEU capacity. Some ports in the US have tariff structures that differentiate according to length of a ship: longer ships pay more. In some cases, such as Los Angeles, this results in a port tariff that is fairly proportional to TEU capacity; in other cases, such as Savannah, the port tariff in relation to TEU capacity tends to level off somewhat (See Annex 6 for illustrations). However, it should be noted that various ports are not transparent about their port tariffs applied, because there is room for negotiation. Considering the market power of the container shipping alliances that use most of the world’s mega-ships, this negotiation might be favorable to mega-ships.

Figure 5.1. **The relation between port dues and container ship size in the port of Gdansk (2014)**



Source: OECD/ITF elaboration based on data provided by port authority and terminal operators

There is a need to develop some basic principles related to the development of mega-ships. One of the key principles could be that the external costs of mega-ships be internalised. These external costs include the adaptation costs of infrastructure and possibly other costs such as congestion and adjustment costs. Internalisation would mean that the costs would be covered by the actor who is at the basis of mega-ship development. It might be in the interest of society at large that further container ship size development be tied towards such cost recovery principles.

Maintenance fees

Various countries have instruments to make sure that external costs related to large ships are – at least partly – covered by the port users. This is for example the case of fairway dues in countries like Sweden and Finland. The idea behind these fees is cover the costs for services rendered to merchant shipping, besides services where the individual user of the services rendered are identifiable. In those cases the principle of user pays is applied and the individual user is charged. So this includes dredging of the fairways. In both countries, the fees are calculated in function of a ship's gross tonnage and the amount of cargo it is loading and unloading at the country's port of call, but the provisions of the Finnish fairway due is designed in such a way that larger ships pay less.[7]

Some countries have an explicit fee for dredging and harbour maintenance. This is the case of the US that has a *harbor maintenance tax* (HMT), a fee charged over the value of the cargo, which is supposed to cover the maintenance works of US ports, including dredging and deepening. The fee was part of the 1986 Water Resource Development Act which requires ports to share the costs of constructing new channels and operating and maintaining channels more than 45-feet deep. Although this user-pays principle could be considered a laudable objective, the HMT has been criticised for various reasons (e.g. McIntosh et al. 2015; Simkins and Stewart 2015). The criticism most relevant for our discussion here relates to cross-subsidisation and the limited correlation between the HMT and the costs it covers. Talley (2007) has argued that the design of the Harbor Maintenance Tax (HMT) and the Harbor Maintenance Trust Fund (HMTF) makes it likely that lower-dredging ports are cross-subsidising higher-dredging cost ports. McIntosh and Skalberg (2010) make a similar point when they argue that there is no evidence that the cargo value is highly correlated with port maintenance costs.

Instruments, such as maintenance fees and fairway dues, could be designed in such a way that the ships that cause exponentially higher needs for maintenance and dredging would also be charged exponentially higher. In the case of the HMT, this could mean including variables are found to be correlated with port maintenance costs, such as tonnage, port stay and draft, as proposed by McIntosh and Skalberg (2010).

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[7] In Finland, all foreign traffic cargo ships calling at Finnish ports have to pay fairway dues. Fees are calculated by multiplying the ship's net tonnage by the unit price for fairway dues. The rates for cargo ship unit prices vary between 1.277 and 6.918 euros in function of ice classes (Norwegian Swedish ship classification system. In opposition to Sweden, the fee to pay per gross-ton is divided by two for ships over 25,000 GT. Finland also applies a maximum due per call of 107,750 euros and a maximum of 10 calls for which the ship has to pay per year. There are a number of provision for rebates on dues such as "*The fairway dues for a cargo ship are reduced by 75 per cent if the ship carries cargo from a foreign port that because of compelling reasons connected with the ship's large size must be transported by other ships from the port of arrival to another Finnish port.*" In Sweden the fee applied is 2.75 SEK per ship GT for cargo ships sailing from foreign traffic at the first port of call in the country or to domestic ships at the port where they load cargo. Ships only have to pay the dues for the two first calls at a given port per month which is less than for other types of ships like ferries (5 calls charged per month). Cargo-based dues are charged with SEK 2.75 per ton of cargo goods and with SEK 1.00 for what is referred to as low value goods (can be defined). Vessels with a nitrogen oxide reduction certificate receive a reduction on the gross tonnage-based fairway dues. The reduction starts at an emission level of 6 g/kWh and falls to less than 0.5 g/kWh, in which case the vessel is totally exempted from gross tonnage-based fairway dues.

Conditionalities in state aid to shipping?

The shipping sector is subject to state aid in many countries, most notably tonnage tax regimes. This form of favourable tax treatment of shipping companies, allows countries to treat shipping companies differently from other firms with respect to corporate taxes. Under the popular "Dutch model" – introduced by the Netherlands in 1996 and implemented by over 20 states around the world – the normal corporate income tax rates are still applied to shipowners' profits, but their profit itself is calculated differently. The tonnage tax under this model sets a given daily profit per ton, which is applied to the total tonnage capacity of the fleet owned by the company and calculated for a full year. The profit thus calculated is then taxed at the country's corporate tax rate, meaning that shipowners are taxed at a flat rate, irrespective of the company's actual profit or loss. While the tonnage tax played an important role in slowing the decline in flag registers amongst traditional maritime states in the preceding decades, it has since become something of an international norm, no longer sufficient to meaningfully contribute to the maritime cluster.[8]

These fiscal schemes provide levers for nations to somehow "regulate" the shipping sector via incentives. Some states, such as the United Kingdom, however have tailored tonnage tax schemes to suit their own national requirements in ways that push the potential of the tax, rather than simply attempting to reduce de-flagging rates (Box 2). It would be possible to consider conditionalities related to recovering external costs from mega-ships. This would work best if coordinated on a supra-national level. E.g. the EU has guidelines for state aid to the shipping sector; these guidelines could be reconsidered in such a way that the container lines are somehow committed to cover certain costs related to mega-ships, such as additional dredging needs.

Box 2. Conditions related to the tonnage tax in the United Kingdom

Eligibility for the tonnage tax in the United Kingdom involves two main requirements. On the one hand, ships must be "strategically and commercially managed in the UK". Several factors are assessed as part of this definition: headquarters and decision-making operations of the company should be located in the UK; activities such as route planning, cargo booking, personnel management, technical vessel management and direction of foreign offices should be carried out in the UK; the overall share of work and number of employees in the UK should outweigh that done elsewhere, vessels should be flagged, classed, insured or financed in the UK, and so on. This ensures that the loss of potential taxation through the implementation of the tonnage tax regime is amply compensated for through increased activity in the UK maritime service cluster. On the other hand, the UK tonnage tax regime includes a "training commitment", which requires participating companies either to train officers and cadets (who must be British or EU nationals), or to transfer funds to the Maritime Training Trust. This requirement effectively builds a human capital matching mechanism into the tonnage tax regime, ensuring that the maritime cluster remains embedded in the UK labour market. Since its introduction in 2000, the UK tonnage tax has been credited with reversing the decline in shipowners and operators in the UK, and contributing to threefold and six fold growth in the UK-owned and UK-registered fleets respectively during the 2000-09 period (MaritimeUK, 2012). The policy has furthermore been credited with contributing an extra 189 700 jobs to the UK economy (direct, indirect and induced), and with more than doubling the shipping industry's GDP contribution, as compared with what it would otherwise have been (Oxford Economics, 2013).

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[8] In addition to the regimes described here, governments might undertake bilateral measures to increase opportunities for shipping companies. These include reciprocal tax exemption agreements (RTEs), agreements for the avoidance of double taxation (DTAs), and comprehensive DTAs (CDTAs). The logic behind such bilateral agreements, in which the parties agree to reciprocally exempt ship operators from certain taxes in both countries (RTEs) or in one only (DTAs and CDTAs), is that they foster trade relationships, improve the competitiveness of the maritime cluster and enhance its attractiveness for ship operators. Maritime and trade-dependent countries often form such agreements. New Zealand, for example, had 37 DTAs in force in 2013, with five signed and not yet in force, and seven more under negotiation. Additionally, Section CV 16 of New Zealand's Income Tax Act 2007 allows for income exemptions for any state in which reciprocal exemptions are made for New Zealand ship operators, meaning that most of its DTAs can also effectively function as RTEs.

Financial transparency of ports

Many ports throughout the world receive public subsidies, whilst at the same time having commercial functions. In the case of mega-ships, this situation risks to lead to situations where the public sector picks up the bill of costs imposed by shipping lines. Especially where ports are engaged in fierce competition to attract mega-ships, port authorities might be tempted use public funds to attract these, or to cross-subsidise mega-ships by raising higher tariffs on other ship size, ship types or other activities. There is no inherent public interest in stimulating mega-ships, so there is no reason why public funds should be used to favour mega-container ships relative to smaller ships, especially if the external costs of mega-ships are not recovered.

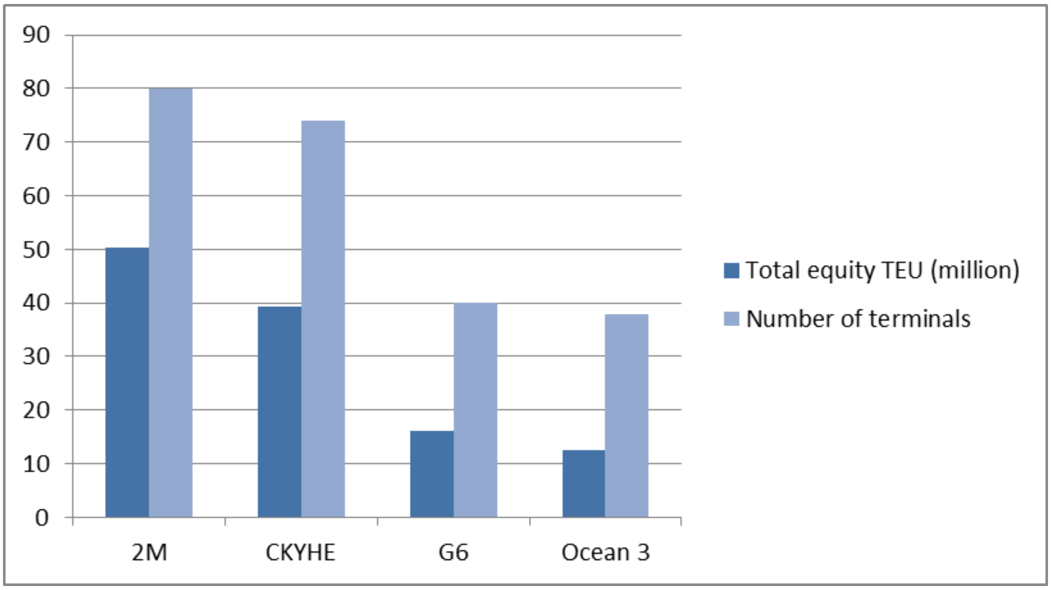
Greater transparency would be needed in port finance, in order to avoid that mega-ships receive public subsidies. This transparency is currently lacking; there are various ways in which countries are indirectly subsidizing port activities, e.g. by fiscal exemptions, cheap energy, access to finance and infrastructure investments to improve maritime and land-side access of ports. Legal and policy frameworks need to be strengthened in this respect, preferably between nations because port competition is in many places taking place beyond national boundaries. The EU Ports Policy Package stresses the importance of financial transparency of ports; this could be a basis that could be extended and strengthened to ensure that public funds are not used to stimulate mega-ships, with mechanisms to recover public and external costs related to mega-ships. In addition, state aid rules and their application to the ports sector could be clarified.

Collaboration

Cooperation of shipping lines on landside operations

Shipping lines realise that they need to cooperate more with respect to landside operations, because this is where more cost savings are to be reaped. This is most clearly the case at US West Coast where the port terminals are mostly in the hands of the shipping lines. Due to the emergence of alliances, an important share of the vessels are now shared with alliance partners, but the vessels still call at each individual terminal because of their links with the individual shipping company. E.g. in Los Angeles, five of the G6 members have their own terminal assets. Similar situations exist in ports elsewhere in the world (e.g. Hong Kong). Each carrier has a strong incentive for their vessels on a service to call at their terminal, because terminal costs are not shared, because the approach to terminals can be different (some run as profit centres, some as cost centres) and because it would lead to difficult negotiate within the alliance on rates to be charged to alliance partners (Widdows, 2015). More cooperation of shipping lines on land operations could take various forms, possibly also in the form of equity stakes in port terminals and ports. In this respect, the four alliances and their members have already been quite active, with large terminal portfolios in the hands of some shipping lines (Figure 5.2), in many cases in strategically located transhipment hubs. Shipping lines have also been active in developing hinterland transport operations, in the future they might do this more jointly with their alliance partners.

Figure 5.2. **Container shipping alliances and their stakes in terminals**



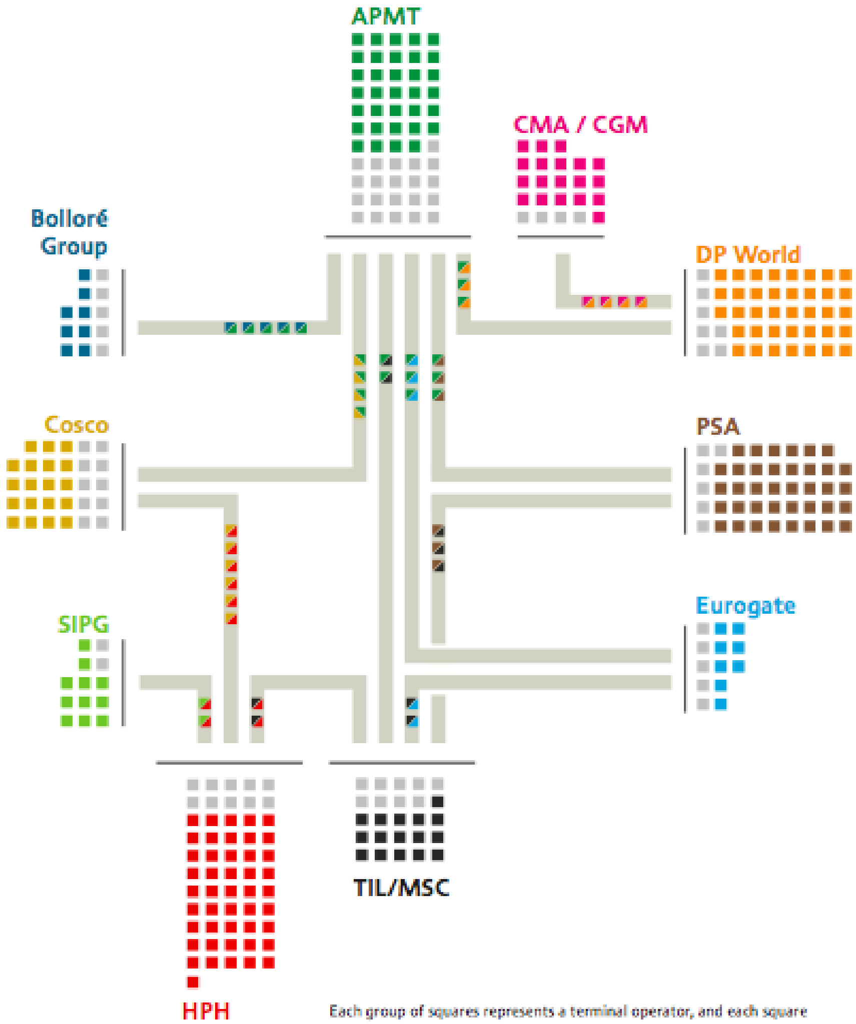
Source: own elaborations based on Drewry 2014

This will require finding a balance between competition and internalisation of costs. It could be in the interest of supply chains that shipping lines internalise the costs that they cause by ordering mega-ships; at the same time this vertical integration of shipping activities with terminal and hinterland transport operations might raise the concerns of competition authorities. This might necessitate better global coordination of regulatory approaches to competition of container lines.

Cooperation between terminal operators

Cooperation between terminal operators is not unusual. Since the proliferation of the landlord model of port governance – in which the port authority keeps certain regulatory functions but delegates port operations to private operators – various countries have adopted legislation that only allows global port operators in joint ventures with local operators, in many case with a majority stake of the local operator. What is fairly new is the cooperation between the largest global terminal operators. For some global terminal operators these joint ventures start to make up a substantial part of their terminal portfolio. For the moment, most of these joint ventures are concentrated in certain geographical areas, in particular China, West Africa and North Europe, but the number of joint ventures of global terminal operators is expected to grow (Drewry, 2014). Some terminal operators have also stakes in other operators, most notably PSA that has a 20% stake in HPH. Although certain pairs of terminal operators are more common than others (Figure 5.3), it might be too early to conclude that alliances of global terminal operators are emerging.

Figure 5.3. **Joint ventures of global port terminal operators in 2014**



Each group of squares represents a terminal operator, and each square represents a terminal. The grey squares represent the total numbers of terminals jointly operated (joint ventures). The squares inside the lines represents the number of terminals jointly operated between two operators.

Source: OECD/ITF based on Drewry 2014

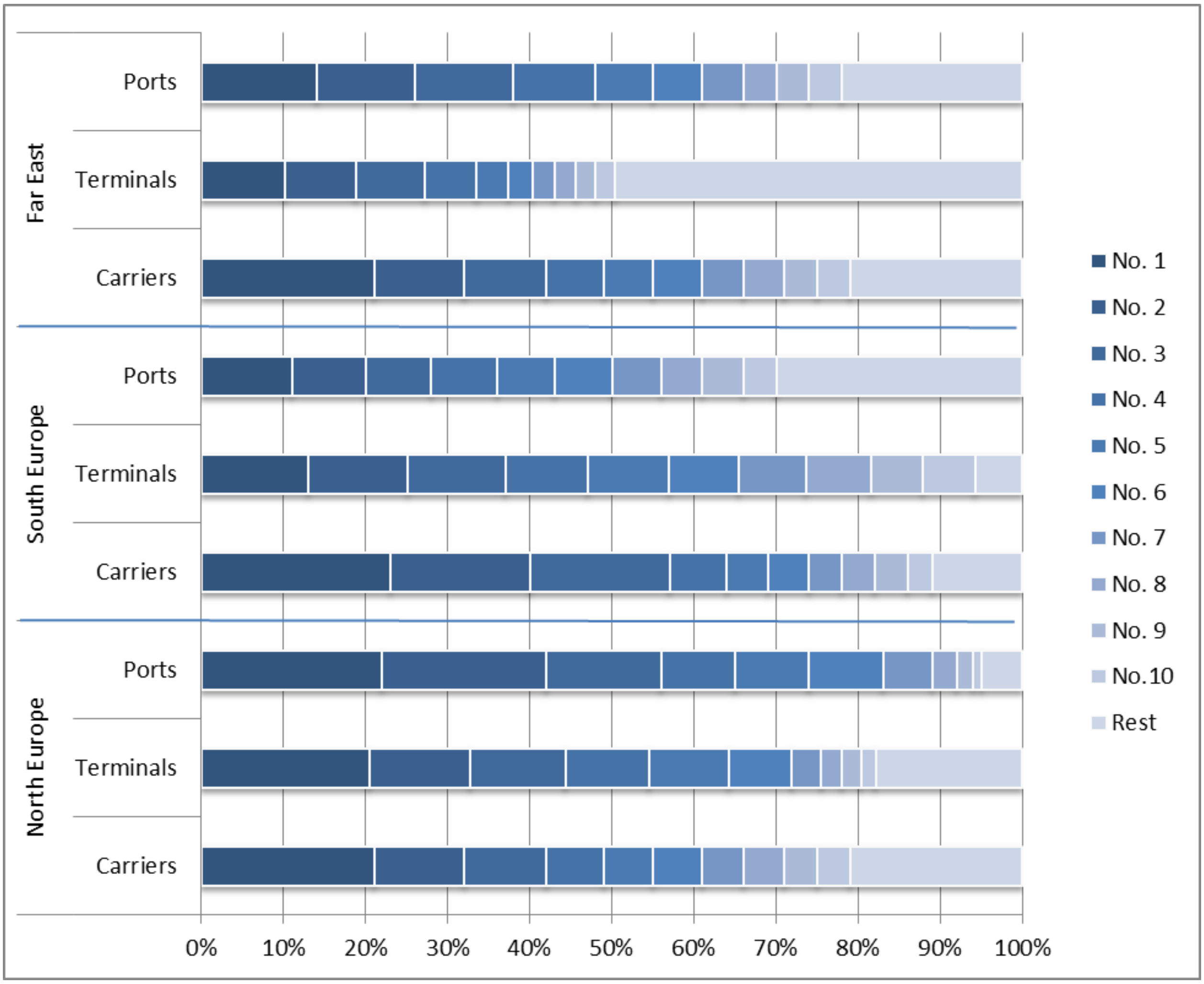
This might at some point become a concern for competition authorities and legislators. The effects of terminal cooperation and consolidation will differ from place to place, and general guidelines are not all together straight forward. A reasonable amount of competition between port terminals is clearly in the public interest, also because competition between ports is in many places limited because of their natural gateway functions that cannot easily be replaced by other ports. At the same time, the reality of mega-ships would sometimes suggest the consolidation of certain terminals, e.g. in order to create the required berth lengths or yard space. Sometimes, port laws are restrictive in the terminal extensions they allow; e.g. in Mexico the Port Law stipulates that port terminals can extend their area up to 20%; if they would like to exceed such limit, they would need to bid for a new terminal (OECD, 2015). The alternative is relocation of part of the port, which could be disadvantageous to incumbent port terminal operators, considering that they are frequently excluded from bidding for reasons of competition. In some countries with terminal fragmentation, port laws would need to be evaluated in order to assess if the legislation is "mega-ship-ready", that is: providing enough flexibility to terminal operators and port authorities to re-negotiate concessions within the light of changing realities fuelled by mega-ships.

Coordination of port development and investment

The power balance between shipping lines and ports has shifted towards shipping lines. This is partly related to the consolidation of shipping lines, which has taken place at a much faster pace than consolidation of ports, which remains exception rather than common practice. While ports have to woo four alliances of container lines, the carriers have a wide choice of ports where they could call. E.g. even if the six main North European ports for intercontinental traffic from cargo have a market share of approximately 85%, these ports know that other ports have capacity to compete for these market shares; and in many cases shipping lines seem to keep certain direct calls to smaller ports going in order to keep their options of possible ports to call large enough. Many ports, also very large ports, are quite dependent on one single shipping line or alliance; if this carrier would stop to call the port, this would result in a large decline in port volume. This gives the shipping line strong bargaining power vis-à-vis ports, only enforced by the fact that carriers have movable assets, whereas the assets of ports are highly fixed.

There is a large difference between regions in the world. This can be illustrated by market shares of the top 10 carriers, terminals and ports in their respective areas. In North Europe, the market shares of ports are higher than those of carriers and terminals, in complete contrast to South Europe where the market shares are much lower, in particular in comparison with carriers, and to a lesser extent with carriers that are more fragmented in South Europe than they are in North Europe. Yet, terminal fragmentation is much larger in the Far East, where the top 10 terminals have only half of the market share; in the Far East both carriers and ports are less fragmented (Figure 5.4).

Figure 5.4. **Concentration of container carriers, terminals and ports in Europe and Asia**



Source: own elaborations based on Drewry 2014, Dynamar 2015 and own data collection

Port competition has its merits, but in many cases also generates oversupply of port capacity with public funds, offering greater choice and bargaining power to shipping lines. Places with intense port competition can build up new port capacity far in excess of current demand. This can be considered visionary in case of spectacular economic growth rates, but is more problematic when and where growth is fairly stagnant. These situations can raise concerns, because large shares of the port infrastructure or port hinterland infrastructure will have been funded with public money only to provide more choice to carriers. In order to get a return on investment, the ports then compete to attract these carriers by providing incentives.

The challenge for public policy is to balance port competition and avoiding public over-investment. Too much port competition could lead to overcapacity, whereas strict public investment planning could lead to governments second-guessing market intentions; so the balance is delicate. There are two ways to achieve this: first, by upsizing ports; and second, by providing strategic port planning at the appropriate territorial level.

Port mergers

The upsizing of ports is fairly rare, but is increasingly taking place. Cooperation between ports is common, in particular on issues where interests are common or aligned, such as their regulatory functions. With respect to commercial functions, port cooperation is much rarer and in essence only possible if the profile of the cooperating ports is different enough to provide room for synergies. Nevertheless, there is a growing number of port mergers, mostly for assumed cost savings, but sometimes also to create more critical mass in order to improve the bargaining position of the port. Notable examples in this respect are Port Metro Vancouver, the Japanese super-ports, Ningbo-Zhushan and the on-going merger of the ports of Seattle and Tacoma. In Europe, despite the much-acclaimed merger of the ports of Copenhagen and Malmö – special because of its cross-border nature -, there are relatively few port mergers – and if they take place, these are usually between relatively small ports, such as Hamina-Kotka, Vlissingen-Terneuzen and other local ports.

Mergers between ports under local government control are not common, but there are some cases in which locally controlled ports have merged. Proximity and the presence of a common threat (e.g. Oresund Bridge in the case of Copenhagen and Malmö) seem to be a strong determining factor for mergers. In many cases, there was some kind of national pressure to realize such a merger and overcome local rivalries, but there are also examples where local port authorities decided on this relatively autonomously. Central governments typically have other motives for mergers (e.g. avoid duplication, more rational investment planning, avoid destructive competition between national ports, achieve a specialisation of ports) than local governments (e.g. securing capacity for growth elsewhere when own capacity for expansion is limited, neutralize competing ports, broaden the choice available to customers, etc..) In some cases, port mergers have coincided with port decentralisation reforms; e.g. in France and China. We suppose that the increasing dominance and bargaining power of shipping lines could form a determinant for various ports and the governments in charge of these ports to increasingly consider mergers of their ports.

Port mergers fit in a larger picture of port regionalization, in which port authorities increasingly seek consolidations or acquisitions of other seaports or inland ports in the area that could help to improve port-hinterland connectivity (Notteboom and Rodrigue, 2005). Greater autonomy of port administrations facilitates these participations. In some cases the port authority participates directly (cf. Antwerp) while in other cases a port authority subsidiary, port operating company or investment holding related to the port authority is involved in the participation (e.g. Shanghai International Port Group - SIPG as operating entity of the Shanghai port authority). Also, it is important to underline that the participation can involve pure landlord functions (such as land management) while in other cases the port authority also takes part in the actual terminal and or logistics operations (cf. SIPG on the Yangtze River). A port authority acting as landlord of a seaport area might consider to act as tool port in an inland port.

Strategic planning

The second way to counterbalance the growing dominance of shipping lines could be strategic planning of port development and investment at the right territorial level. Much depends on the way ports are governed: locally, regionally or nationally; and how this finds it way in policies and infrastructure investments.

Various countries have established a national port hierarchy, so somehow define a port system in which some ports are of “national importance” whereas other ports merely represent regional or local importance. This is of particular impact if these ports of national importance also receive a priority treatment in terms of funding. The hierarchy determines in many cases which ports are governed nationally and which ones locally. Table 5 provides an overview of the countries that make legal distinctions between their different ports and, as such, have established some sort of port hierarchy.

Table 5.1. **Port hierarchies in national policies**

Country	Port hierarchy
Canada	19 Canada Port Authorities (CPAs), 26 remote ports; in addition to regional or local ports
France	7 ports of national importance (GPMs), in addition to regional or local ports
Greece	12 ports of national interest
India	13 major ports, 187 non-major ports
Indonesia	25 strategic ports
Ireland	5 ports of national significance (Tier 1 and 2), 14 ports of regional significance
Italy	23 ports of national importance; in addition to ports of regional relevance, military ports
Korea	28 international trading ports, 23 coastal (local) ports, 9 new ports
Poland	3 ports of national importance
Portugal	5 main seaports, 4 secondary ports
Spain	44 ports of general interest, ports of non-general interest

Source: Merk forthcoming

National involvement in ports often takes the form of investment in port infrastructure or port-related infrastructure, such as hinterland corridors and dredging. Canada, with its Atlantic Gateway, is an example. Established in 2007, the Atlantic Gateway Federal-Provincial Officials Committee promotes ongoing collaboration between the Government of Canada, the four Atlantic Provincial Governments, and the private sector in the development of the Atlantic Gateway and Trade Corridor. The Atlantic Gateway and Trade Corridor is a fully integrated multimodal transportation system that offers deep water ports, efficient and reliable road and rail networks with access to U.S. markets, and airports with air cargo access to/from international markets (Atlantic Gateway website). National governments are frequently responsible for dredging programmes and are able to sustain port hierarchies via these investments. This is for example the case in the US where the Harbor Maintenance Trust Fund (HMTF), appropriated by US Congress, is used by the US Army Corps of Engineers to dredge and other maintenance operations. Brazil also has a large national dredging programme, which serves as an implicit mechanism to establish a port hierarchy.

Although port policies at the national level could help to define priorities for public spending in ports and port-related infrastructure, one could wonder if such coordination should not also take place at the level where port competition takes place. In North Europe, this could for example be at the level of the Hamburg-Le Havre range. However, coordination at this intervention level hardly takes place: although the directors of the main ports in the area meet regularly, they do not discuss coordination of commercial or strategic development; coordination of transport ministries in these countries does not seem to include port strategic planning. As a result, the last years have seen a large supply of additional port capacity in the area.

The European Union has done an effort with its core network of ports within the context of the Trans-European transport network TEN-T. It has not only formulated a comprehensive port network, but also prioritised within this network by designating 104 core ports. Although fairly exceptional in its sort, it falls short of making real choices. Trimming down the number of priority ports is an achievement in itself, but the process also shows the dynamics of such efforts, with political interventions motivated by national interests and equity concerns rather than public efficiency motives, which raised the number of core ports from 83 to 104. What would be needed now is a much more strategic focus on what would be the main ports and port corridors serving European shippers, consumers and producers.

China has also a supra-national vision on main ports. The land-based Silk Road Economic Belt starts from Xi'an and stretches north to several key cities in Central Asia like Almaty, the largest city in

Kazakhstan, then crosses Iran, Turkey and Russia, before reaching Germany and Netherlands. The Maritime Silk Road will begin in Quanzhou in Fujian province, pass through Guangzhou (Guangdong province), Beihai (Guangxi), and Haikou (Hainan), before heading south to the Malacca Strait. From Kuala Lumpur, it will stretch to Calcutta, India and Nairobi, Kenya, then go north around the Horn of Africa and cross the Red Sea into the Mediterranean, with a stop in Athens before meeting the land-based Silk Road in Venice. This supra-national vision is backed up with infrastructure investments, also in port hinterland infrastructure; and raises the question of the relation between the EU and Chinese strategies.

The US does not have an explicit federal ports or freight policy. With regards to port access one could argue that there is an implicit federal policy, namely via the appropriated spending of the Harbor Maintenance Trust Fund. However, the HMTF spends structurally less on ports than the revenues it receives from the Harbor Maintenance Fee, and also here spending tends to take place according to political criteria rather than public efficiency criteria. A more explicit federal freight policy could help to provide the framework for prospective development of US ports.

Regulation of mega-ship development?

Will the market regulate itself?

There are precedents in shipping where ship size development has stabilised, and even declined. This is notably the case of crude oil tankers. The 1970s saw the emergence of Ultra Large Crude Carriers (ULCCs) with more than 500,000 dwt capacity, and a carrying capacity 3.7 million barrels. Most of the largest ULCCs have been scrapped since the 1980s or reconverted to other uses. Several reasons can explain such a backdrop, including the 1973 and 1979 oil crises that lead to decrease in demand that led to the destruction of ships that where too expensive to maintain without demand for such capacity. Numerous oil spills in the 1980s and the 1990s pressured policy makers to impose the removal of single hull tankers (including the supertankers) to the benefit of double hull carriers. Finally, the ULCCs could not be deployed very flexibly, considering their draft of 20 metres, which is prohibitive for most ports and indeed many maritime straits. Similarly, in the airline industry the development of ever larger airplanes seems to have stalled (Box 3).

Box 3. Ever bigger airplanes?

Since the dawn of the jet age, aircraft size has grown significantly, going from the 36 to 44-seat DeHavilland Comet in 1951 to the 452-seat Boeing B-747 in 1969 and the 520 to 853-seat[9] Airbus A-380 in 2005. Aircraft capacity growth was achieved through the introduction of the twin aisle in the B-747 and a second passenger deck in the B-377(1947), the B-747 and A-380. However, aircraft manufacturers have not been racing to build a bigger airplane; rather, they have been racing to build a better airplane. Therefore, has passenger capacity for commercial aircraft reached its maximum?

While the bigger planes may constitute the most eye-catching segment of aircraft manufacturing, in fact it is the smaller, single aisle, short to medium range aircraft that constitutes the bulk of the fleet. In 2014 alone, aircraft manufacturers Airbus and Boeing received combined orders of 2,425 narrow body aircraft (A-319/320/321, B-737) compared 450 small to medium widebodies (A-330/350, B-777/787…) and only 13 large widebodies (all A-380). In the past two decades, Boeing and Airbus developed two very different visions of how airline networks would evolve; Boeing thought airlines would favour “hub busting”, enabling passengers to fly directly point-to-point and bypass large, congested hubs and long connection times. Airbus, on the other hand believed the future of air travel would be articulated around very large aircraft, mega-airplanes, operating on high density trunk routes and connecting 42 cities

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[9] Depending if it is in a 3-class or full economy configuration

which it considered major global hubs. These hubs would have traffic fed from smaller, secondary airports.

At the heart of this debate is the trade-off between economies of scale provided by operating larger aircraft and the flexibility that comes from operating a larger fleet of smaller aircraft, in a world where technology had made range a non-issue on the majority of routes[10]. The A-380 also requires some infrastructure upgrade, such as wider taxiways and double-bridge gates that means most airports either cannot accommodate that aircraft or only a very limited number simultaneously. In addition, few routes worldwide generate enough traffic, including higher yield First and Business Class traffic, to sustain a profitable A-380 operation. Finally, the four engines required to power the A-380 or B-747 add significant cost compared to operating a twin-engine small or medium widebody aircraft.

This divergence in philosophy led Boeing to develop first the B-777 and then the smaller B-787 while Airbus developed the A-380 to serve the global hubs as well as the smaller A-330/340 family for smaller, long-range markets. It turns out that both were partially right in their approaches, with airlines increasingly articulating their long range networks to connect their home mega-hub with both mega hubs and secondary airports, but favouring frequency over capacity to better exploit connection banks at hub airports, thus providing greater connectivity options for their passengers. In addition, the emergence of airline alliances and metal-neutral joint ventures helped carriers better manage capacity, which is greatly facilitated through the use of a smaller aircraft.

Over the last two decades, airlines' long-haul route networks have grown by connecting their hubs to secondary markets and increasing frequency on trunk routes rather than connecting spoke airports and bypassing hubs entirely. During this time, the medium and long-haul network saw a doubling of the number of city pairs served, frequency and capacity, while the average airplane size has actually declined slightly and is now about 10 percent smaller than it was in the early 90s. Even in the 42 airports that Airbus has identified as mega hubs, since 2000, the number of cities served increased with 42 percent since 2000, and capacity with 58 percent. Yet average aircraft size is down 2 percent. This reflects the fact that opportunities for growth do not reside solely between mega-cities but rather between secondary points. It is also the result of a more liberalised global aviation marketplace which has enabled the establishment of new routes and increased frequencies on existing routes. Finally, it shows that smaller aircraft offer operators more flexibility to match capacity to demand and more opportunities to increase aircraft utilization. As a result, today, the A-380 flies to less than 50 airports worldwide, compared to over 250 for the B-777. No operator flies the A-380 in a full economy configuration, indicating the existence of limits to possible economies of scale.

This trend away from "mega-airplanes" is also reflected in manufacturer's order books. Between 2005 and 2014, Boeing and Airbus reported orders for over 3,050 small or medium wide-body aircraft (capacity of 250 to 400 seats) compared to 330 for the large wide-body A-380 and B-747 combined. Operators of the A-380 have been very concentrated, with Emirates (59 aircraft) and Singapore Airlines (19 aircraft) operating half of the 156 aircraft delivered so far. In contrast, eight carriers operate half the global fleet of B-777 and 18 carriers operate half the global fleet of A-330. Turning to the future, this trend is expected to continue or even accelerate. Boeing forecasts sales of small and medium wide-bodies over the next two decades to outpace sales of large wide-bodies by a 13 to 1 ratio, while Airbus expects that ratio to be 9 to 1. Boeing's next wide-body aircraft, the B-777-9X will have a capacity of around 410 seats whereas the largest aircraft Airbus is developing is the 369 seats A-350-1000[11]. This is not to say there would not be a market for new mega-airplanes but clearly both leading manufacturers do not consider it sufficiently important to off-set aircraft development costs.

For nearly half a century, aircraft manufacturers have had the technology to produce mega-airplanes. The commercial success of the A-380 and B-747 certainly indicates that a market for such aircraft exists, but that market is increasingly limited. Airlines today are seeking aircraft flexible enough to accommodate a wide number of routes and provide passengers with better connectivity through increased frequency. This makes the carrier better equipped to manage seasonal variability in demand, better able to develop new markets and favours the building of alliance-based networks. Manufacturers have responded to these needs by targeting long-range aircraft development to the higher end of the medium wide-body market and not to the mega-aircraft niche. Thus, one can conclude that airline economics, and not technology, has capped the potential growth of the mega-airplane and yes, for the foreseeable future, we may have indeed reached peak-passenger capacity for commercial aircraft.

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[10] All three aircraft have ranges exceeding 14,000 km

[11] Both in 3-class configuration

Executives from container lines – to the extent that they have spoken publicly about this - have until now declared that development of even larger container ships would not be very practical and not foreseeable in the near future. In the tradeoff between more economies of scale (of larger ships) and more flexibility and frequency of calls (of smaller ships), the calculation with the currently projected trade volumes is that larger ships would reduce the service frequency to such a level that would not be favourable. Following the logic of such statements, this would imply that somewhere in the next decade the deployment of 24,000 TEU ships would be considered practical by shipping lines; this might be accelerated if the industry gets more consolidated when some lines merge or will go bankrupt.

Could ship size be regulated?

It is theoretically possible to regulate the maximum size of ships. There is a whole body of international regulation that deals with ship design and characteristics, mainly to guarantee safety, security but also better environmental performance. It is not likely that international regulations limiting ship size will ever be accepted by the IMO, dominated by the largest shipping nations, but it is possible that regulation on other elements could act as a brake to development of even larger ships. In the past, the regulation on double-hull tankers has not only contributed to the scrapping of the single-hull super tankers, but possibly also to the stabilisation of tanker size. Although the current and potential new mega container ships have limited associated safety, security and environmental issues, a possible concern could arise with respect to the impossibility of salvage operations of these ships under some circumstances. Considering the typical regulatory reflex after maritime disasters, a future accident with a mega-containership could change the dynamics on the current situation.

There are a few examples where mega-ships are banned in certain ports: very large cruise ships in Venice and the Valemax ore carriers in Chinese ports (see Boxes). The motivations of these bans are varied and both bans are currently expected to be of limited duration.

Box 4. Venice Cruise Ship Ban

The case of Venice shows the complexities of attempts at capping the ship size in ports. Venice, one of Europe’s most popular cruise ports, has seen striking increases in the size of cruise ships calling its port. This has not been appreciated by certain local groups and associations that consider these vessels a risk (and an aesthetical insult) to the city, considering that ships access the port via an access channel (the Giudecca Canal) just beneath the city’s most renowned landmarks, such as the San Marco square.

If large ships had been criticised for long in Venice, it is the Costa Concordia accident that suddenly amplified reactions and fears about the venue of such vessels in the city. The idea of banning large vessels, pushed especially by a petition by the association “No Grandi Navi” increasingly gained media coverage and international interest forcing governments at the local, regional and national levels to find a solution. In 2014 two successive decisions were taken at the national level, the first preventing more than five ships over 40,000 GT to pass through the city per day and the second banning completely from the Guidecca ships from 96,000. However in January 2015, the Veneto Regional Court of Appeals overturned the decision judging that the ban should be lifted until an alternative solution is made available, considering the contribution of the cruise industry to the regional economy. Cruise lines anticipated implementation of the ban and do no longer deploy ships over 96,000 GT. Despite the removal of the ban they are reluctant to bring such large ships again in Venice because of the reputation repercussions it would generate. For the year 2014, this has resulted in a 300,000 passengers decrease compared to 2013. This loss will not be recovered at least until 2016 or 2017. Venice Port Authority has been working on an alternative route, with a new access channel, the Canal Contorta San Angelo. The new route of the Canal Contorta San Angelo would avoid passing through the Giudecca Canal but would imply significant dredging in the lagoon. This has provoked a new outcry from environmentalists.

Box 5. Valemax Ships Ban at Chinese Ports

Vale, a major Brazilian mining company has experienced the effect of the reluctance of a government to host in its ports very large ships. Vale, of the largest iron ore exporters in the world, started ordering dry bulk vessels up with a capacity of up to 400,000 tons in 2008. It bought a fleet of 19 vessels most of which were destined to operate trade between Brazil and China, that consumes over a third of the iron ore market.

These Vale vessels were never allowed to call at Chinese ports. From 2011, China would only allow ships to call on a case-by-case basis and in January 2015 the Ministry of Commerce officially banned Valemax ships from Chinese ports. The main reason advanced to justify this decision was safety concerns as the ports were supposedly not ready to accommodate such large ships. According to some observers the underlying agenda was to protect the domestic shipping and steel industries.

Vale made port calls in Europe and Asia and developed a distribution facility in the Philippines and a transshipment center in Malaysia to be able to keep providing its Chinese customers. A process to lift the ban started in 2014 when Vale signed two contracts with large Chinese companies. The first was a strategic cooperation agreement with Cosco involving 14 ships for 25 years. The second was signed with China Merchants Group for 25 years also and 10 ships operating the trade between Brazil and China. If the ban had not been lifted yet, in practice restrictions were over, with most formers supporters of the ban agreeing that these contract were going along with the country’s interest. The final step the issue was the Circular 9 issued by the Chinese Government that officially amended the Design Code of General Layout for Sea Ports to include vessels of 400,000 capacity, instead of the former 350,000 limit, therefore allowing Valemax to call at Chinese ports legally.

China has regulated the maximum dimensions of the container ships that are allowed in its ports. This means that shipping lines wanting to exceed those limits have to engage in a discussion with the Chinese government to get permission, or to get the regulations changed to their new vessels. Considering that the largest container ships are constructed for the Far East-Europe trade lane, if the European Commission would impose a similar maximum limit on containerships as China this would in practice come close to a global maximum of container size.

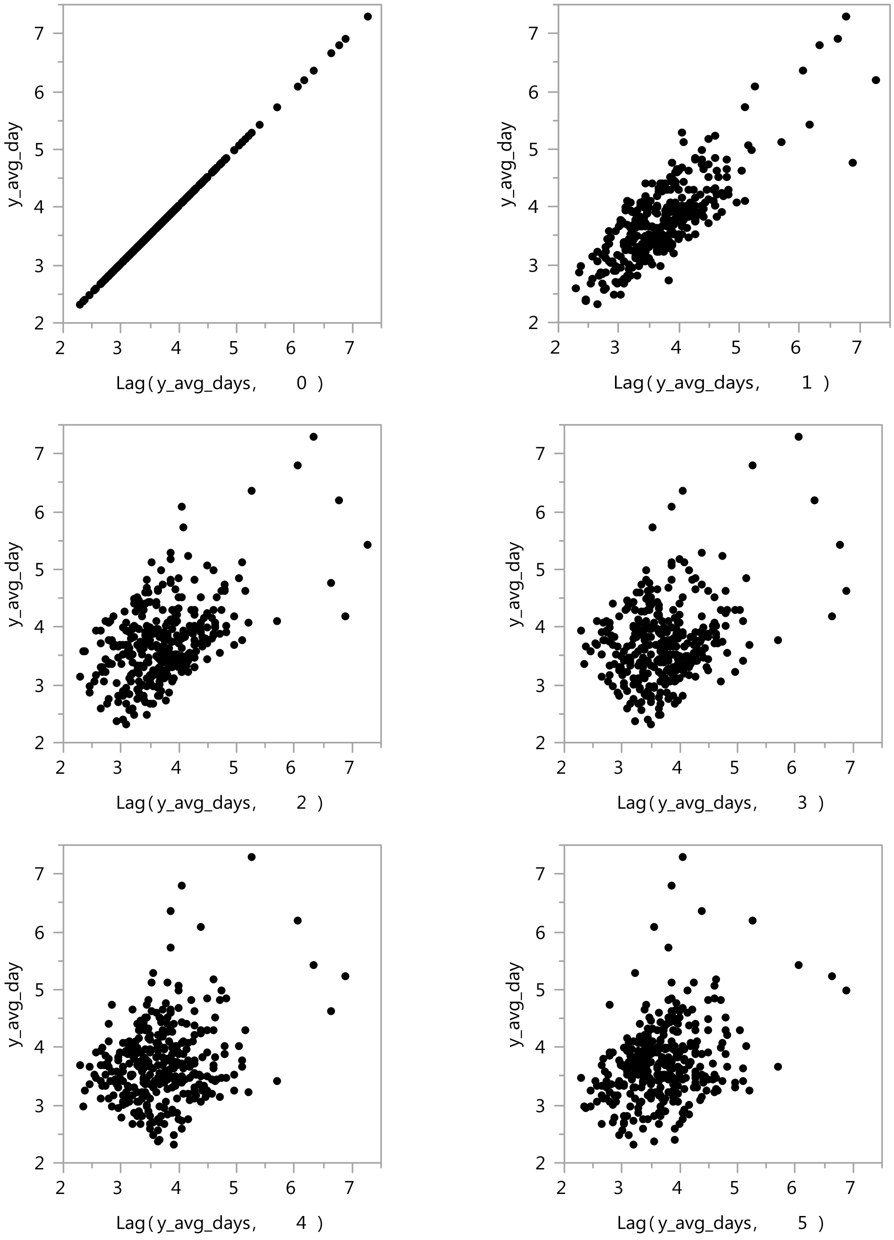
Governance of the supply chain

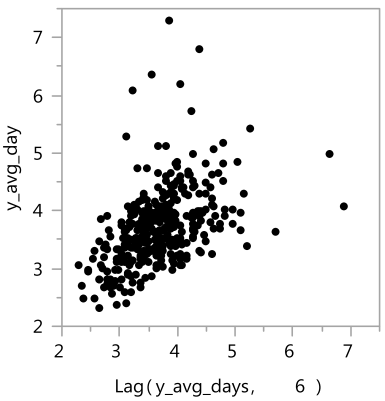
The emergence of mega-ships raises the issue of speediness of public decision-making. Whereas it takes approximately one and a half year between the order and delivery of a ship, the time for adaptations to infrastructure usually take longer. Dredging might take several years, extension and strengthening of quay walls one to two years, port hinterland connections easily more than five years, and new port terminals at least five but frequently more than ten years if land needs to be reclaimed. For most of these adaptations, the actual time for construction or doing the works is relatively short, but it is the decision-making process that often takes most time. Most of these projects are sensitive, considering that they involve many stakeholders with different interests and often diverging conceptions of a desirable outcome. Inevitably, a lot of time is invested in consultation and – where possible – creating consensus on a concrete proposal, followed by various impact assessments (feasibility, cost/benefit analyses, economic, environmental and social impacts), planning permits, bidding processes for procurement or public-private partnerships. Frequently, stakeholders that oppose a proposal will use every legal possibility to block smooth decision-making on the proposal. In practice, it can take decades before projects see the light; in many cases projects never materialise. In the context of accelerating growth of container ship size, this is a substantial challenge: there is a huge divide in lead time between the decision to order and delivery of a mega-ship, and the decision and realisation of infrastructure works needed to adapt to mega-ships. In addition, some of the landside investments are substantially higher and fixed, whereas ships are movable assets that can be deployed flexibly. This would suggest the need for a more organised and planned transition of mega-ship development in the future, similar to the one for the introduction of the A380 airplane.

Container lines have typically not consulted anyone on new mega-ships, before they ordered these. A constructive discussion would need to take place with the relevant transport stakeholders, including governments, regulators, port authorities and all interested constituents. The objective could be to facilitate an exchange of views, an understanding of objectives and plans, and ultimately better coordination to ensure optimum supply chain configurations.

Annex 1. Yard utilisation related to mega-ships

In port terminals with one weekly call of a mega-containership, there seems to be a cyclical 7-day pattern in yard utilization (day **x** vs day **x** + ***0 to 7***):




y_avg_day
7
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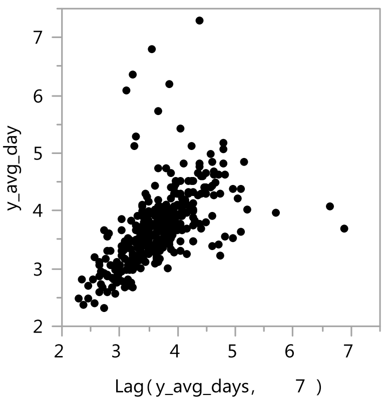
Lag(y_avg_days, 6)


y_avg_day
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7
Lag(y_avg_days, 7)

Annex 2. Calculations economies of scale of mega-ships

The three large cost categories of the shipping industry are the capital-, operation-, and voyage costs. The key to understanding the economies of scale of the latest generation of fully cellular tonnage is to understand how these respond to changes in vessel size. The analysis will focus on the elements that are directly ship related, i.e., the capital costs, operating cost and propulsion consumption

Capital costs

The capital costs of the units are determined by the newbuilding price as well as the cost of finance.

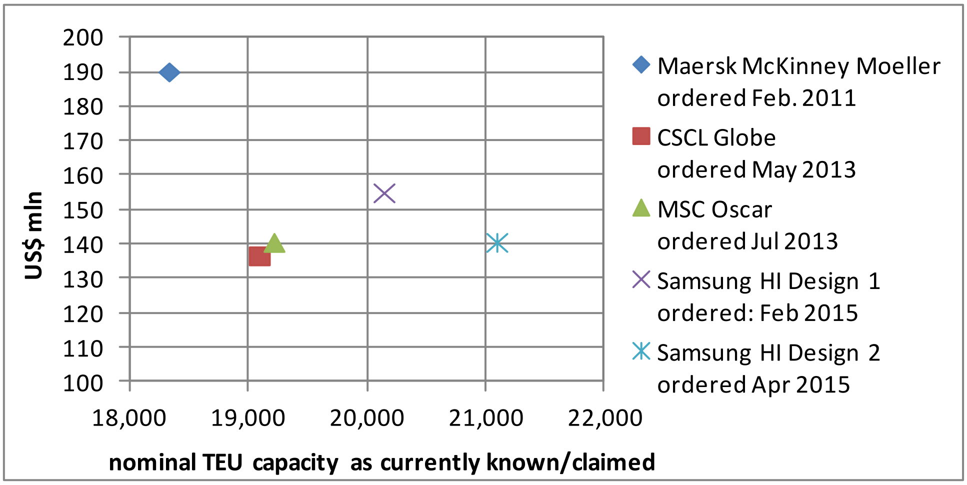
Newbuilding prices

When nominated in US$, the prices for new container ships are influenced by

- Exchange rates
- The price of steel as well as the
- supply/demand-balance of the yards

at the time of contract. As a result, the analysis of the economies of scale of newbuilding prices must at least take into consideration the time during which the vessels are ordered. Otherwise, a first glance at the recently ordered vessels would suggest a surprising relationship between ship size and vessel value:

Reported newbuilding prices of representative units of the latest generation of fully cellular vessels (not adjusted for market price fluctuations)



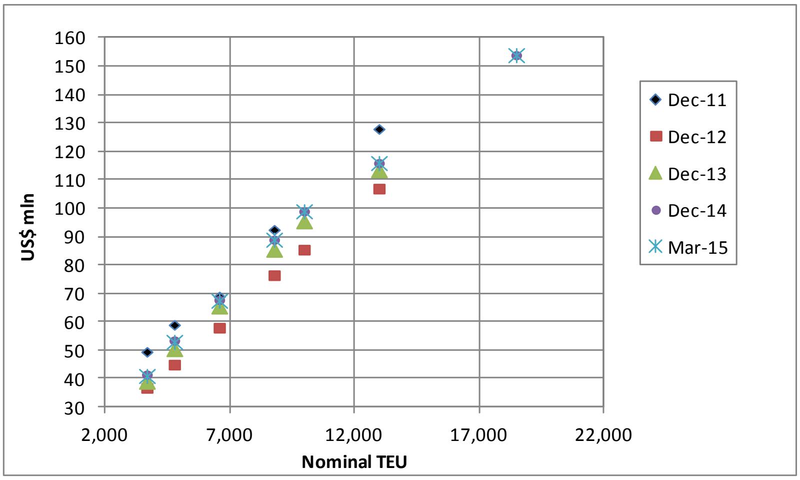
Source: Own elaboration, collected from various sources.

The following chart analyses the newbuilding prices of fully cellular units quoted by CRSL (Clarksons Research Services Limited) at different points during recent years. It reveals that:

a) the relationship between size and newbuilding prices is surprisingly linear in the medium sizes and that

b) at different times, the newbuilding prices vary strongly, yet the proportions seem to be consistent.

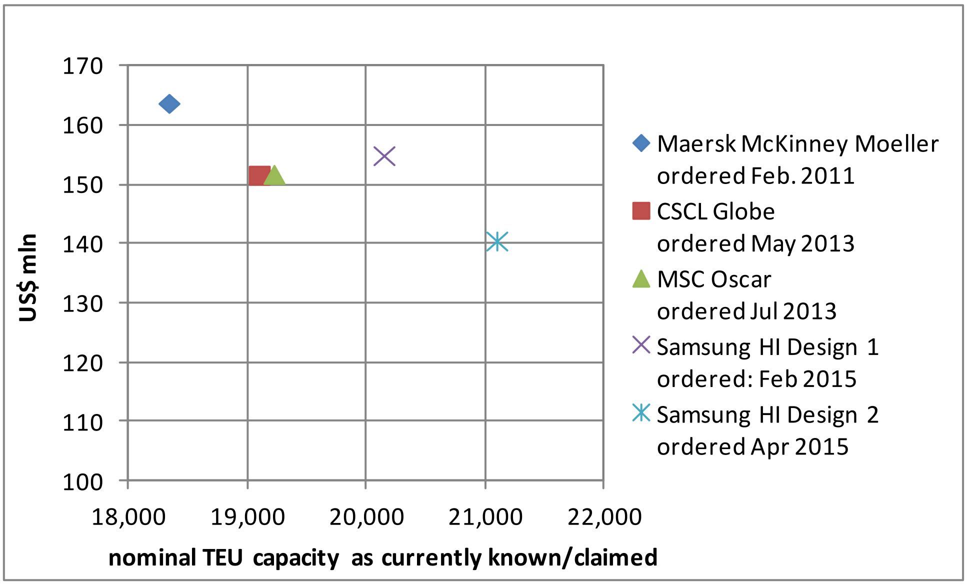
Newbuilding prices of standard fully cellular post-panamax units, 2011-2014 (at year end), March 2015



Source: Own elaborations, based on data from Clarksons Research Services Limited (CRSL).

It follows that the newbuilding prices of the fully cellular units must be viewed in relation to the time frame in which the vessels have been ordered and hence deflated accordingly. For this purpose, the CRSL Newbuilding Price Index was used. After making the newbuilding prices comparable, it seems that the Triple-E units have been ordered at a relatively high price. This is most likely attributable to the innovative design and the twin-engine concept which will drive the cost.

Reported newbuilding prices of representative units of the latest generation of fully cellular vessels (adjusted for contract date market prices)

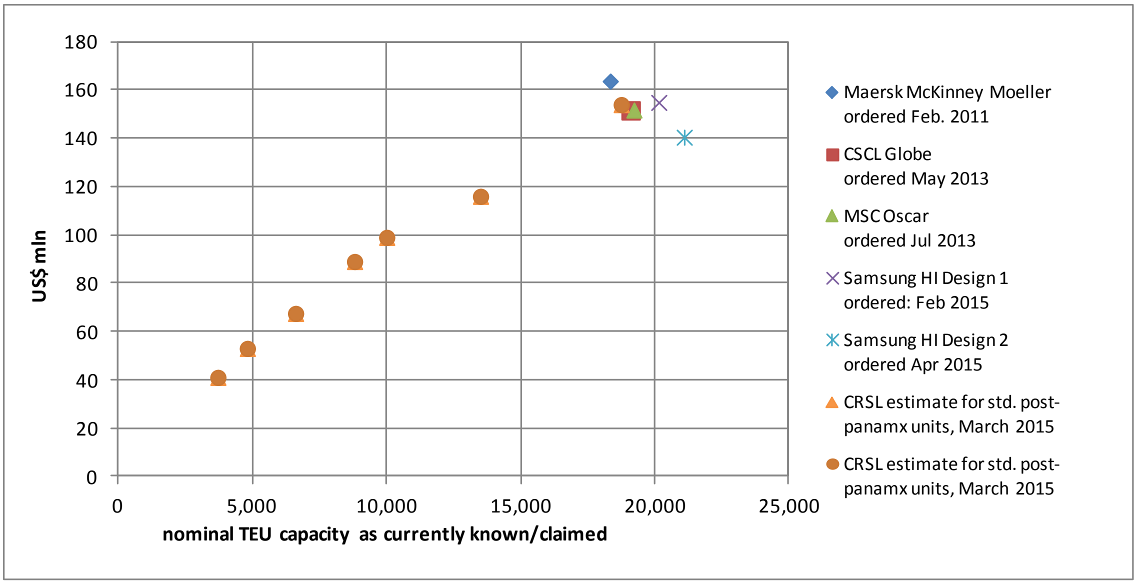


Source: Own elaborations

Later single engine ~19,000 TEU units and the recently ordered Samsung designs with capacities of 20,150 TEU and 21,000 TEU respectively thus outperform the Maersk vessels in terms of newbuilding prices and hence capital cost.

At the start of 2015, a new time-series for newbuilding prices appeared in Clarksons "Shipping Intelligence Network". The series is listed as "18,000-19,000 TEU" and stood at US$ M 154 at the time, when the first 20,150 TEU units were ordered – reportedly for the same price. It stands to be assumed that the price is rather indicative for a range of units. Considering that the per-item-price of the recently ordered 21,000 TEU units was even lower, it stands to be assumed that modern 19,000 TEU designs should be available at a modest discount.

Newbuilding prices of prominent units of the latest generation of fully cellular vessels adjusted for market price fluctuation and compared to prices of std. post-panamax units, early in 2015



Source: Own elaborations, based on data from Clarksons Research Services Limited (CRSL), own scenarios.

Taking the evolution of recent vessel prices and -sizes into account, we estimate that early in 2015, the following newbuilding prices would have been applicable for units of ~8,500, ~15,000, and ~19,000 TEU.

Estimated newbuilding prices and daily capital cost for container ship sizes early in 2015

Capacity (nominal TEU)	~8,500	~15,000	~19,000
Estimated newbuilding price	US$ M 89.0	US$ M 130.6	US$ M 153.0
Capital cost at 5% depreciation, 4% interest,	US$ 21,945/day	US$ 32,203/day	US$ 37,726/day

Source: Own elaborations

Applying a factor of 9 % to the newbuilding price in order to estimate both depreciation as well as interest, the economies of scale of the selected units can be deducted.

Whilst theoretically, the recently ordered 21,000 TEU ships would offer even more favourable economies of scale, they have been excluded from the analysis as their savings per TEU are probably hard to achieve. The analysts of Alphaliner have raised concerns about the effective usability of the nominal capacity of the larger units stating that on heavy headhauls, the deadweight of these units might very well be exceeded before the actual capacity.[12]

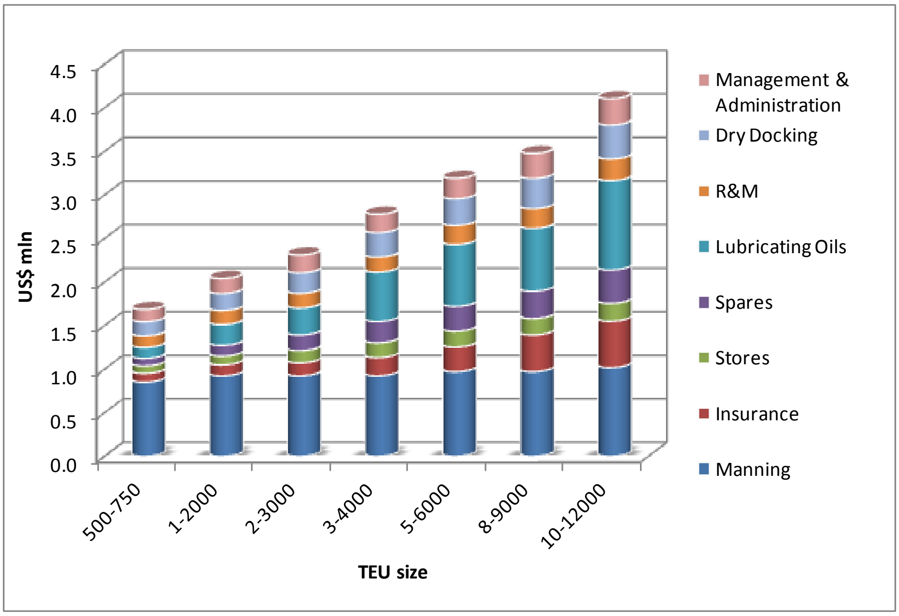
The available information indicates that the capital costs for the units exceeding 16,000 TEU are actually not increasing in a linear manner but slightly below that. The new paradigm of going slow thus seems to contradict the previous fear that the capital costs of larger units would increase super-proportionally as a result of a second main engine being required to maintain the high operation speeds. Hence, it is fair to say, that the new modus operandi of "slow-steaming" has opened the door for the exploitation of further economies of scale as far as capital costs are concerned.

As a result, it is estimated that the ~19,000 TEU units would offer annual savings per TEU-slot (assuming full utilization) of US$ 59 when fully utilized. Assuming a more likely utilization of 85 %, the annual savings per TEU slot of the larger units compared to the previous container ship generation (~15,000 TEU), reach US$ 69. This figure is depending widely on the cost of finance as another per cent of interest will add approximately US$ 7.35 to these savings.

Operating costs

The total operating costs of fully cellular units seem to develop almost in proportion to the vessel size on the surface. A closer look at the research regularly carried out by Drewry Maritime Research reveals that the additional operating cost per TEU per annum are declining, as the vessels continue to increase beyond capacities of 5.500 TEU.

2014 annual operating cost of various container ship sizes



Source: Own elaborations based on Drewry Maritime Research, Ship Operating Costs Annual Review and Forecast 2014/2015.

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[2] C.f. Alphaliner Weekly Newsletter Volume 2015 Issue 09, p 3.

Taking into account the patterns, which can can be observed in the estimates made by Drewry Maritime Research for the cost items:

- Manning,
- Insurance,
- Stores,
- Spares,
- Lubricating Oils,
- R&M,
- Dry Docking, and
- Management and Administration,

We estimate that:

- ~15,000 TEU vessels should have operating costs of ~ US$ mln 4.7 p.a., and
- modern ~19,000 TEU vessels should have operating costs of US$ mln 5.2 p.a.

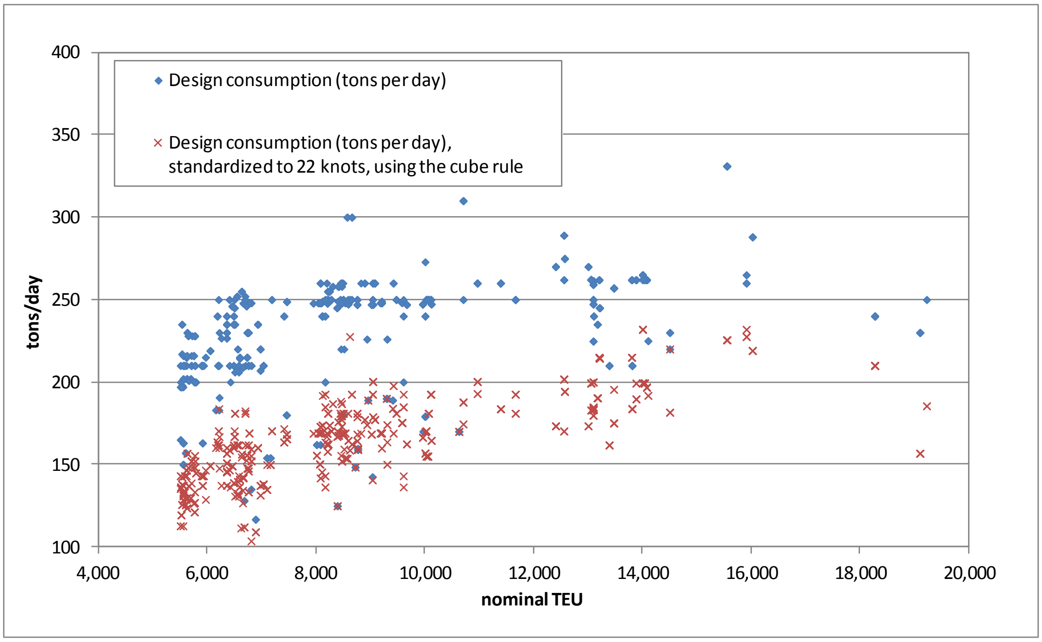
Voyage costs

The economies of scale of the voyage costs can be reduced to the single biggest cost driver: the propulsion consumption of the ships, using an ISL database about merchant vessels and their engine particulars and estimated consumption patterns. To a certain degree this data is dependent on ISL expert estimates as various commercially accessible archives will often list surprisingly different speeds or daily propulsion consumptions for the largest vessels. Carriers are probably well advised to reveal as little true information as possible about their vessels. Otherwise their larger customers, all of whom are typically equipped with transport and logistics departments, could find it surprisingly easy to assess the real impact, bunker price fluctuations should be having on freight rates.

As the speed and consumption patterns of the vessels vary, the daily fuel consumption at design speed (diamonds) which is known/reported/estimated needs to be standardized to an equivalent voyage speed (here: 22 knots, portrayed as crosses) in order to allow for a comparison between vessel sizes.

The diagram shows how astonishingly fuel efficient the modern ~19,000 TEU units seem to be, consuming actually less fuel than some of the first ~14,000-~16,000 TEU units which have been ordered and built with a different mindset.

Daily propulsion consumption of the post-panamax fleet early in 2015



Source: Own elaborations, based on industry data, desk research and own estimates.

Additionally to mere capacity, the beam of the vessels also has an impact on the consumption of the vessels. Estimating the consumption of a ~15,000 TEU unit in a fair manner is a tricky task. The "flagship" of this generation of vessels, the Emma Maersk stands out in both speed and computed consumption (~330t/day at ~25.5 knots (ISL estimate)). Other than that, the first comparable units only showed up as slightly smaller units at later dates and with lower design speeds, yet often being quoted with propulsion consumptions of around 250-270t per day although computations by ISL suggest that at full speed, some of the first 13,000-14,000 TEU units might just as well consume slightly north of 300t/day. All in all it seems a fair estimate to assume that a reference vessel of the second-latest generation of fully cellular units would probably consume 310 tons at a speed of 25.0 knots.

Estimated propulsion consumption and design speed of different containership generations and sizes

	Built ~ 2003	Built ~ 2008	Built ~ 2015
Capacity (nominal TEU)	~8,500	~15,000	~19,000
Estimated design speed	25.0kn	25.0kn	24.0kn
Estimated consumption at design speed	250t/day	310t/day	250t/day

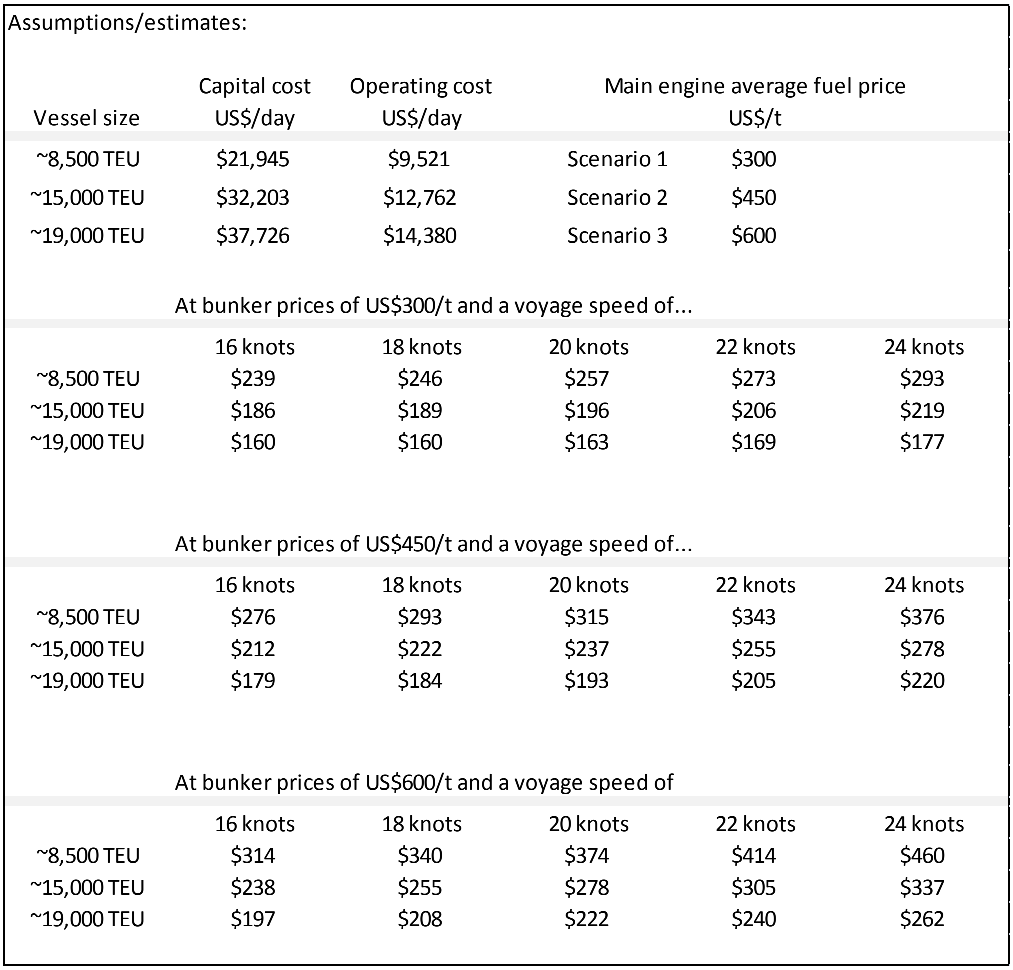
Source: Own elaborations, based on industry data, desk research and own estimates.

The latest generation of container ships on the other hand has daily propulsion consumptions that are almost comparable to those offered by the ~8.500 TEU units built around the years 2003 and following – yet, it can effectively carry more than twice as many TEU.

Economies of scale of modern 19,000 TEU vessels

Using the collected and estimated data, the impact of the economies of scale for the latest two generations of container carriers can be illustrated. Thereby the vessel is deployed on an imaginary round trip and capital costs, operating costs and propulsion related consumptions are recorded.

Capital cost, operation cost and propulsion consumption per TEU on a 21,000nm round trip. 3 weeks presumed tied up for loading/discharging/idle times, 85 % utilization.



Assumptions/estimates:

Vessel size	Capital cost US$/day	Operating cost US$/day	Main engine average fuel price	US$/t
~8,500 TEU	$21,945	$9,521	Scenario 1	$300
~15,000 TEU	$32,203	$12,762	Scenario 2	$450
~19,000 TEU	$37,726	$14,380	Scenario 3	$600

At bunker prices of US$300/t and a voyage speed of...

	16 knots	18 knots	20 knots	22 knots	24 knots
~8,500 TEU	$239	$246	$257	$273	$293
~15,000 TEU	$186	$189	$196	$206	$219
~19,000 TEU	$160	$160	$163	$169	$177

At bunker prices of US$450/t and a voyage speed of...

	16 knots	18 knots	20 knots	22 knots	24 knots
~8,500 TEU	$276	$293	$315	$343	$376
~15,000 TEU	$212	$222	$237	$255	$278
~19,000 TEU	$179	$184	$193	$205	$220

At bunker prices of US$600/t and a voyage speed of

	16 knots	18 knots	20 knots	22 knots	24 knots
~8,500 TEU	$314	$340	$374	$414	$460
~15,000 TEU	$238	$255	$278	$305	$337
~19,000 TEU	$197	$208	$222	$240	$262

Source: Own elaborations, based on industry data, desk research and own estimates.

The resulting cost per TEU seem relatively low at first, especially when compared to e.g. the Shanghai Containerized Freight Index. But it needs to be remembered that these costs are supposed to represent the economies of scale resulting immediately from the vessel. They are focussed on capital cost, operation cost and propulsion consumption. In real life, various other items would need to be considered as well like e.g.

- the notorious imbalance of the Far East trades, leading to the requirement to recover the losses endured on the “backhaul” with higher freight rates on the dominant leg
- the overhead costs of the industry, typically charged per box
- port calling costs
- auxiliary consumptions during idle times
- the cost of supplying containers

- the SCFI is referring to FEU (consuming two TEU slots)

For most of these items it can be stated that they offer only very limited (e.g. port calling cost) or no economies of scale at all (e.g. overheads charged per box or cost of supplying containers). Thus using the estimated operation-, capital-, and propulsion costs provides a good insight into the economies of scale that are attributable to the ships themselves.

At this point, it is worth pointing out that the economies of scale of the last generation of container carriers, the 400m*59m/~19,000 TEU units are largely made possible by the new trend of reduced operation speeds and resulting optimizations of both hull and machinery in this regard. It might thus be questioned whether the conducted comparison is at all a fair one, or if the maritime transport cost of the previous generation of container vessels should rather be compared to units with a technology and design-standard of other vessels ordered around 2005. This will be attempted in the next section.

Inflating the latest generation of fully cellular vessels to the old industry-standard

The previous chapter has already provided two major indications about how the savings per TEU-slot of modern ~19,000 TEU ships are to a certain extent attributable to the change of the modus operandi of the liner shipping compared to the years prior to 2005.

The major implications of the overall reduction in design-speeds speed are that:

- Fully cellular vessels of the latest generation (400m*59m,~19,000 TEU+) can actually be built using just one main engine, which is beneficial for the economies of scale as far as capital costs are concerned

- Being optimized for lower operation speeds, modern vessels can outperform previous generations in terms of fuel efficiency at low speeds although the previous vessels too benefit strongly from fuel savings when reducing the operation speed from a higher design speed (attributable to the cube-rule of fuel consumption).

The impact of slowsteaming on the operation costs is probably rather insignificant. We estimate that if 19,000 TEU vessels had been ordered in 2005 already, the most prominent differences in operation costs would have been attributable to

- Higher insurance premiums (as the larger engines would have made the vessels more expensive in the first place)

- Higher lube-oil consumption

Whilst the previous section concluded with the finding that modern ~19,000 TEU units do provide noticeable cost savings per TEU, especially at high fuel prices, this section will attempt to inflate modern ~19,000 TEU ships to a high-speed standard, which would have applied in or around the year 2005.

The aim is to identify, how much of the savings per TEU (when increasing the ship-size from the initially deployed ~15,000 TEU ships to the modern 19,000 TEU units) actually are attributable to economies of scale and how much of the savings actually result from the benefits of the overall reduction in operation speeds.

This requires some educated estimates as a unit like this has never actually been built. The following analysis is based on two assumptions:

- The engine for this hypothetical "stone-age" ~19,000 TEU design is estimated to be a 16 cylinder, 92,500KW single engine, leading to higher newbuilding prices and thus higher capital costs compared to modern ~19,000 TEU units.
- Design-consumption for said engine is estimated to be ~ 380t / day at a design speed of 25.5 knots.

Capital cost, operation cost and main engine fuel consumption per TEU of on a 21,000nm round trip. 3 weeks presumed tied up for loading/discharging/idle times, comparing ~8,500 TEU and ~15,000 TEU units with a hypothetical "fast" ~19,000 TEU ship, 85% utilization.

Assumptions/estimates:

Vessel size	Capital cost US$/day	Operating cost US$/day	Main engine average fuel price US$/t	
~8,500 TEU	$21,945	$9,521	Scenario 1	$300
~15,000 TEU	$32,203	$12,762	Scenario 2	$450
~19,000 TEU*	$38,589	$14,479	Scenario 3	$600

**** hypothetical design ordered around the year 2005***

At bunker prices of US$300/t and a voyage speed of...

	16 knots	18 knots	20 knots	22 knots	24 knots
~8,500 TEU	$239	$246	$257	$273	$293
~15,000 TEU	$186	$189	$196	$206	$219
~19,000 TEU*	$172	$175	$181	$190	$202

**** hypothetical design ordered around the year 2005***

At bunker prices of US$450/t and a voyage speed of...

	16 knots	18 knots	20 knots	22 knots	24 knots
~8,500 TEU	$276	$293	$315	$343	$376
~15,000 TEU	$212	$222	$237	$255	$278
~19,000 TEU*	$196	$205	$218	$235	$255

**** hypothetical design ordered around the year 2005***

At bunker prices of US$600/t and a voyage speed of

	16 knots	18 knots	20 knots	22 knots	24 knots
~8,500 TEU	$314	$340	$374	$414	$460
~15,000 TEU	$238	$255	$278	$305	$337
~19,000 TEU*	$220	$235	$255	$280	$309

**** hypothetical design ordered around the year 2005***

Source: Own elaborations, based on industry data, desk research and own estimates.

Annex 3. Cascading effects following 24,000 teu ships

The following “what-if”-scenarios have been developed as a part of this study:

a) The capacity of the fully cellular fleet will grow in line with market demand growth during the next five years. Thereby the total fleet capacity will expand by roughly one third and contain no units of a new generation of mega carriers with capacities of up to 24,000 TEU by the year 2020.

b) The capacity of the fully cellular fleet will grow in line with market growth demand during the next five years. Thereby the total fleet capacity will expand by roughly one third and contain **50 units** of a new generation of mega carriers with capacities of up to 24,000 TEU by the year 2020. The new 24,000 TEU units would to a large extend replace investor demand for ~19,000 TEU ships and on their own contribute a million TEU to the growth of the supply side.

c) The capacity of the fully cellular fleet will grow above market demand growth during the next five years. Thereby the total fleet capacity will expand by roughly one third and contain **100 units** of a new generation of mega carriers with capacities of up to 24,000 TEU by the year 2020. This is a very aggressive assumption and the competitive implications would be severe, leading to a spontaneous spike in tonnage surplus und thus trigger a further round of additional scrapings of older and smaller units. Also, the sudden spike in orders for these vessels would imply a strong shift of orders from the otherwise expected orders for 18,000-21,999 TEU vessels.

Other than that, the scenarios share the same basic assumptions:

- Scrapping will be based on age structure and lead to ongoing fleet stagnation below ~2,000 TEU
- Old panmax-designs will continue to lose relevance fast, scrapping of older 3,000-4,000 TEU units continues, yet these units are partially replaced with wide-beam designs.
- There will be a continuous demand for larger units of the currently known dimensions, predominantly for the 13,000-15,000 TEU size range, while only few additional contracts are expected for vessels with capacities of ~16,000 TEU.
- The Nicaragua-canal is not expected to have an impact on vessel design or investment decisions by the year 2020.

The over-proportional ordering of very large ship units is not a new phenomenon. Quite the contrary: As the above analysis has shown, liner operators have repeatedly introduced larger ship sizes during the past. This long experience also gives a good indication of what happens when a new, larger container vessel concept is introduced: it is almost always initially deployed on the North Europe-Far East trade which has seen by far the largest ships on average in the past years. However, these vessels do not stay on this trade. The reason is simple: the ships have a lifetime of roughly 25 years – several generations when it comes to the container fleet. In 1995, the largest container ship had a capacity of roughly 5,000 TEU; today, the smallest ship on the North Europe-Far East trade has a capacity of 4,400 TEU (and these are not more than a handful in 2015); the average is already above 10,000 TEU.

This development is the main driver for the cascade effect: the new entries crowd out smaller units that are transferred to other trade lanes. There, they are replacing smaller units that are moved to yet another trade lane, and so forth. Based on time series analyses, ISL has developed a model of the cascade effect which allows to forecast the impact of a changing fleet structure on the deployment of container vessels. This model has been used to make the estimations below.

The ISL Fleet Deployment Model is based on the observation that the choice of the trade lane is – in the long-term perspective – not based on a container ship’s absolute TEU capacity, but rather on their relative size with regard to the total fleet. Through the decades, port infrastructure was adapted to the growing ship sizes as no port wants to be dropped from the major services due to ship size restrictions. A notable exception is the trade passing through the Panama Canal: here the maximum ship size has not changed since about a hundred years, limiting the ship size to the Panamax type (i.e. around 297 metres long and 32.3 metres wide). With increasing container ship sizes, the routes passing through the Panama Canal lost attractiveness. As a result, the Transpacific trade between Asia and North America increasingly passes through the U.S. West Coast ports. The Panama Canal extension will make these routes relatively more attractive again and will lead to changing trade routes in place in 2020.

In the first step, each ship’s deployment is estimated based on its relative position in the total fleet. More precisely, the model is based on the percentile of the total fleet capacity in which the ship is situated if the vessels are ranked by TEU. Here, the Panama Canal has lost ground since 1995 – at a time when more than 99% of all container ships could pass through the Panama Canal.

Relative ship size of Selected Panama Canal routes 1995 and 2015 (average percentiles)

Trade routes	1995	2015
Europe - America - Asia / Round-the-world	64	39
North Europe - Latin America	43	28
Far East - Latin America	38	36
North America - Latin America	16	21
All Panama canal routes	44	29

Source: Own elaborations, based on data from MDS Transmodal

Size development scenario A

	Average TEU capacity		Post-Panamax		Post-New Panamax	
Trade routes	**2015**	**2020**	**2015**	**2020**	**2015**	**2020**
Far East-North Europe	11750	14674	97%	100%	30%	67%
Far East-Mediterranean	8574	10500	65%	82%	16%	33%
Far East-North America	6636	7773	48%	82%	0%	10%
Europe-North America	4357	4972	21%	45%	0%	0%
Other East-West	7092	8291	58%	85%	1%	16%
North-South	3931	4384	13%	35%	0%	1%
South-South	2955	3354	0%	15%	0%	0%
intra-Asia	2114	2338	4%	12%	0%	1%
Other regional	1648	1777	2%	5%	0%	0%
Total	**3995**	**4483**	**20%**	**34%**	**2%**	**7%**

Source: Own elaborations, based on data from MDS Transmodal

Size development scenario B

Trade routes	Average TEU capacity 2015	Average TEU capacity 2020	Post-Panamax 2015	Post-Panamax 2020	Post-New Panamax 2015	Post-New Panamax 2020
Far East-North Europe	11750	15474	97%	100%	30%	68%
Far East-Mediterranean	8574	10894	65%	81%	16%	37%
Far East-North America	6636	7886	48%	83%	0%	11%
Europe-North America	4357	4964	21%	46%	0%	0%
Other East-West	7092	8416	58%	87%	1%	17%
North-South	3931	4442	13%	34%	0%	2%
South-South	2955	3358	0%	14%	0%	0%
intra-Asia	2114	2388	4%	12%	0%	1%
Other regional	1648	1796	2%	5%	0%	0%
Total	**3995**	**4555**	**20%**	**34%**	**2%**	**7%**

Source: Own elaborations, based on data from MDS Transmodal

Size development scenario C

Trade routes	Average TEU capacity 2015	Average TEU capacity 2020	Post-Panamax 2015	Post-Panamax 2020	Post-New Panamax 2015	Post-New Panamax 2020
Far East-North Europe	11750	16730	97%	100%	30%	69%
Far East-Mediterranean	8574	11842	65%	83%	16%	44%
Far East-North America	6636	8328	48%	85%	0%	13%
Europe-North America	4357	5196	21%	47%	0%	2%
Other East-West	7092	9004	58%	87%	1%	21%
North-South	3931	4608	13%	36%	0%	3%
South-South	2955	3514	0%	12%	0%	0%
intra-Asia	2114	2415	4%	13%	0%	1%
Other regional	1648	1846	2%	6%	0%	0%
Total	**3995**	**4720**	**20%**	**34%**	**2%**	**7%**

Source: Own elaborations, based on data from MDS Transmodal

Annex 4. Patents related to port terminal productivity

A patent search was undertaken through the OECD Patent Database to weight the state of the art of new technologies to improve terminal operations efficiency and to determine their provenance. Thanks to the World Intellectual Property Organisation's (WIPO) International Patent Classification (IPC), a selection of codes was established relevant to the study. The search resulted in the selection of five codes under which port equipments and terminal operating systems were classified under the IPC.

The codes are the following:

- B66C19: Cranes comprising trolleys or crabs running on fixed or movable bridges or gantries (B66C 17/00 takes precedence; base-supporting structures with legs B66C 5/00; adaptations of girders or of track-supporting structures B66C 6/00; jib cranes B66C 23/00) [2006.01]
- B66C5/02: Fixed or travelling bridges or gantries, i.e. elongated structures of inverted-L- or of inverted-U-shape [2006.01]
- B66C17/20: Overhead travelling cranes comprising one or more substantially-horizontal girders the ends of which are directly supported by wheels or rollers running on tracks carried by spaced supports (adaptations of girders or of track-supporting structures B66C 6/00) [2006.01] .. for hoisting or lowering heavy load carriers, e.g. freight containers, railway wagons [2006.01]
- B65G67/60: Loading or unloading vehicles (by means incorporated in the vehicles B60-B64, e.g. B60P 1/00, B61D 9/00, B63B 27/00, B64D 9/00) [2006.01]. Loading or unloading ships (arrangement of ship-based loading or unloading equipment for cargo or passengers B63B 27/00) [2006.01]
- B65G63/00: Transferring or trans-shipping at storage areas, railway yards or harbours; Marshalling yard installations [2006.01]

The search resulted in a selection of 936 patents filed to the European Patent Office (EPO), to the US Patent and Trade Mark Office (USPTO) or applications filed in virtue of the Patent Cooperation Treaty (PCT) published by the WIPO over 12 years (2000 to 2012).

The availability of information such as country of application and country of invention added as well as name of applicants enabled to highlight several elements.

Annex 5. Transport costs related to mega-ships

Annex 2 of this report described the methodology for calculating cost savings from ordering a modern 19,000 TEU ship in comparison to a modern 14,000 TEU ship. Considering the current order book and the ships already in operation, there will be at least 72 of such ships around in 2017. The sections below will assess the costs for the whole transport chains related to 72 19,000 TEU ships in 2017. In order to do this, we will conduct a thought experiment to see in what respect the impact of these 72 19,000 ships would be different from the handling of the equivalent fleet capacity but in 14,000 TEU ships (so 98 14,000 TEU ships). We willingly ignore existing port capacity to be able to study the effect of upsizing in isolation.

For both the 19,000 TEU and 14,000 TEU we use the following assumptions:

- Utilisation rate of 85% with a TEU/box ratio of 1.65
- Deployment on Far East-North Europe route; with a round trip of 21,000 nm, with three weeks per voyage tied up for port stay, and 55 days at sea. Speed of of 16 knots is assumed, which means that the number of voyages is 4.82 per year.
- 15 port calls per voyage; 6 in North Europe, 9 in Far East. We assume that of the 21 days approximately 6 days is reserved as buffer time to be able to accommodate waiting time, delays, and the time from the pilot point to the berth. Average port time (time at berth) is 23.6 hours.

With respect to the ports the following assumptions:

- Each port has loading and unloading moves.
- Gantry crane productivity of 20 moves per hour.
- A ratio of 4 rail mounted gantry cranes per ship to shore crane
- A ratio of 6 straddle carriers per ship to shore crane
- The 72 19,000 TEU ships (or 98 14,000 TEU ships) will generate 934,000 of port volume on average in each of the six North European ports and 623,000 TEU in each of the nine Far East ports.
- We assume 1000 TEUs handled per metre of quay per year, and 580 square metres of container yard per metre of quay; based on current practice in a selection of large European and Asian ports.

Based on these assumptions, the following parametres are taken into account:

- Average port call size for the 19,000 TEU ship in North Europe is 3263 TEU, and 2175 in Far East; for the 14,000 TEU ship the port call sizes are 2404 and 1603 respectively. So the increased port call size (additional peak) is 36%.

- Considering the crane productivity of 20 moves per hour, the assumed port time of 23.6 hours and the average port call size, the number of cranes needed for handling 19,000 TEU ships is 6.9 in North Europe and 4.6 in the Far East, this is 5.1 and 3.4 respectively for 14,000 TEU ships.

- Based on the cargo generated per port, and the assumed ratio between cargo and metres of quay, we calculate a hypothetical quay length and a hypothetical container yard surface.

- The LOA of 19,000 TEU ships is 400 metres; this is 370 metres for 14,000 TEU ships, so the increase in LOA due to the upsizing is 8%. We assume that this is the extent of the upsizing of the quay (and subsequently the yard) needed to accommodate the larger vessels.

The additional costs have been calculated as follows:

- More cranes. In the ports in North Europe 1.8 more cranes are needed (6.9 -/- 5.1). In the ports in the Far East 1.2 more cranes are needed (4.6 -/- 3.4). The unit price for a modern STS crane (Super Post-Panamax) is assumed EUR 10 million. Depreciation period is 15 years.

- Retrofitting cranes. One of the differences between a 14,000 TEU and a 19,000 TEU ship is the difference in beam (52m vs 59m), which means that the first ship can have rows of 20 containers, whereas the latter can have 23 rows of containers. This has consequences for the outreach needed of the STS cranes. We assume that retrofitting an existing crane for increasing outreach costs EUR 2.5 million; with depreciation period of 15 years. We suppose that the existing cranes would need to be retrofitted, so that is 5.1 cranes in the case of the ports in North Europe and 3.4 cranes in the case of the ports in the Far East.

- Straddle carriers. We suppose that half of the ports have a container yard system with straddle carriers. The calculation is based on the assumptions on the number of additional STS cranes needed and the SC/STS-ratio. The unit price for a straddle carrier is assumed to be EUR 0.8 million. We suppose the depreciation period is 8 years.

- Rail mounted gantry cranes. We suppose that the other half of the ports have a container yard system with rail mounted-gantry cranes. The calculation is based on the assumptions on the number of additional STS cranes needed and the RMG/STS-ratio. The unit price for a RMG is assumed to be EUR 3 million. We suppose the depreciation period is 8 years.

- Quay length. We assume that the quay wall needs to be lengthened in line with the LOA increase of a 19,000 TEU in comparison with a 14,000 TEU ship. The unit price for an additional metre of quay wall is assumed to be EUR 45,000,-. We suppose the depreciation period is 50 years.

- Yard surface. As there is no land market for container terminals, there are no direct market prices to rely on. The annual rental price for a industrial land is supposed to provide a reasonable shadow price for land of container terminals. This is approximately EUR 50 per square metre per year. The assumption is that this land is actually available, which is in many ports a problematic issue, considering land constraints. We have ignored that this constraint might lead some terminals to relocate to other areas, which could be considered a more costly option than extending existing terminal yards. The additional land needed due to the 19,000 TEU ships is derived from the increase in quay length and the assumed ratio between quay length and yard surface.

- Dredging. The draught of a 19,000 TEU ship is 16 metres, this is 15.5 metres for a 14,000 TEU ship. So for some ports the maritime access conditions (depth of access channel, river, berths) would need to be improved via dredging. We assume that this is the case for a third of the ports. We assume that approximately 20 million m^3 would need to be dredged, with an assumed unit price of EUR 12 per m^3 and a depreciation period of 20 years.

- Port rail links. Larger peaks make it more necessary to quickly get containers out or to the port via rail. We assume that in half of the ports, the increased peaks due to larger ships would require the construction of an additional rail track to link with existing rail networks. We assume the needed track to be 2 kilometres long, with a unit price of EUR 5 million for one kilometre of rail track, and a depreciation period of 30 years.

- Urban congestion costs. We assume that approximately 75% of hinterland traffic to and from the ports goes by truck, but that only the cargo that is unloaded from a vessel could aggravate urban congestion, as cargo to be loaded on a ship could be scheduled to arrive in the port at an off-peak hour. This means that we consider that only half of the cargo related to the larger peak (due to the larger call size) might aggravate urban congestion. We suppose that the peaks related to larger ships will only aggravate urban congestion in one fourth of the cases, supposing that most port-cities are congested twice a day for two hours (during peak hours) but that there are no trucks coming to the port after 10pm and before 6am. We suppose that the price for inland haulage per truck is EUR 2.5 per full FEU (forty foot equivalent unit), and that the time loss due to the additional congestion represents 10% of an average trip of 150 kilometres. For the Far East the price for inland haulage is assumed to be a third of the one for North Europe. We do not take into account the costs of congestion for road traffic users other than the trucks going to and from the port.

- We assume that the peak effects are being accommodated by the flexible labour arrangements (such as labour pools) without additional costs, even if this in practice is often not the case in many ports.

- We assume that the energy needed to power equipment is proportional to handling volumes and not ship-size dependent.

- With respect to maritime services, we suppose that there are two developments that even each other out: on the one hand the larger average size of ships means that less maritime services (such as mooring, towage and pilotage) per TEU will be needed. On the other hand, some of these maritime services become more expensive as ships grow; e.g. bigger ships need more and stronger tugboats, in some territories ships need more than one pilot if the ship reaches a certain size.

- We assume that there are no costs of finance for the additional investments needed.

- The costs are underestimated because there will be more ports on the Far East-North Europe trade lane that make adaptations in order to attract the largest ships. The six main North European container ports for direct calls on the Far East-North Europe trade lane represent 83% of the volume end 2014, but there were fourteen North European ports with direct calls of the largest vessels. A similar underestimation takes place for the ports in the Far East.

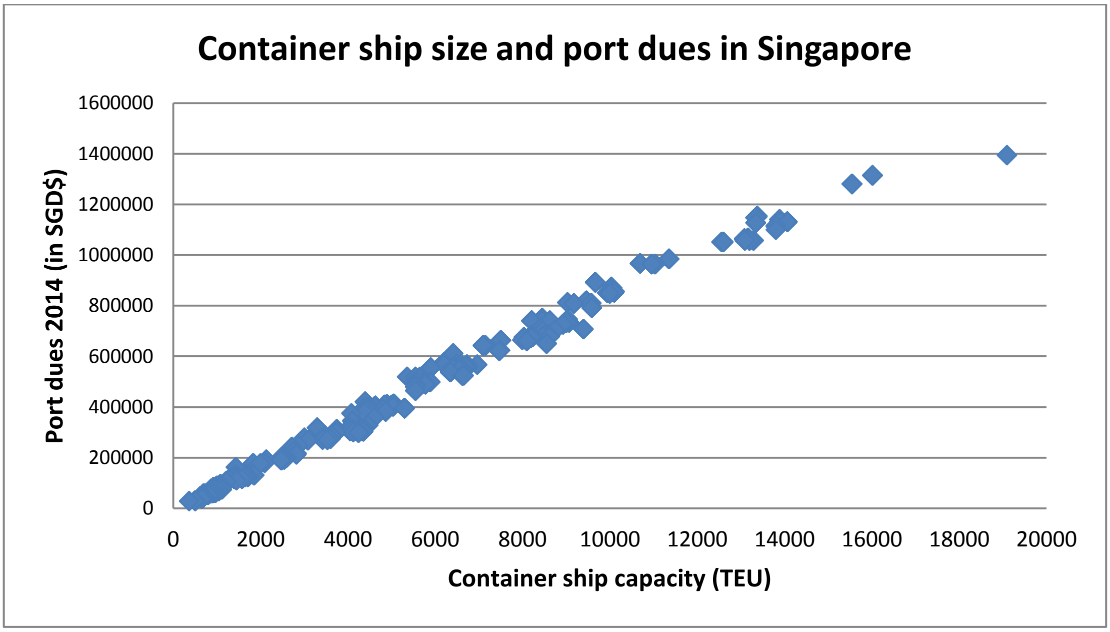
Assumptions about cascading effects

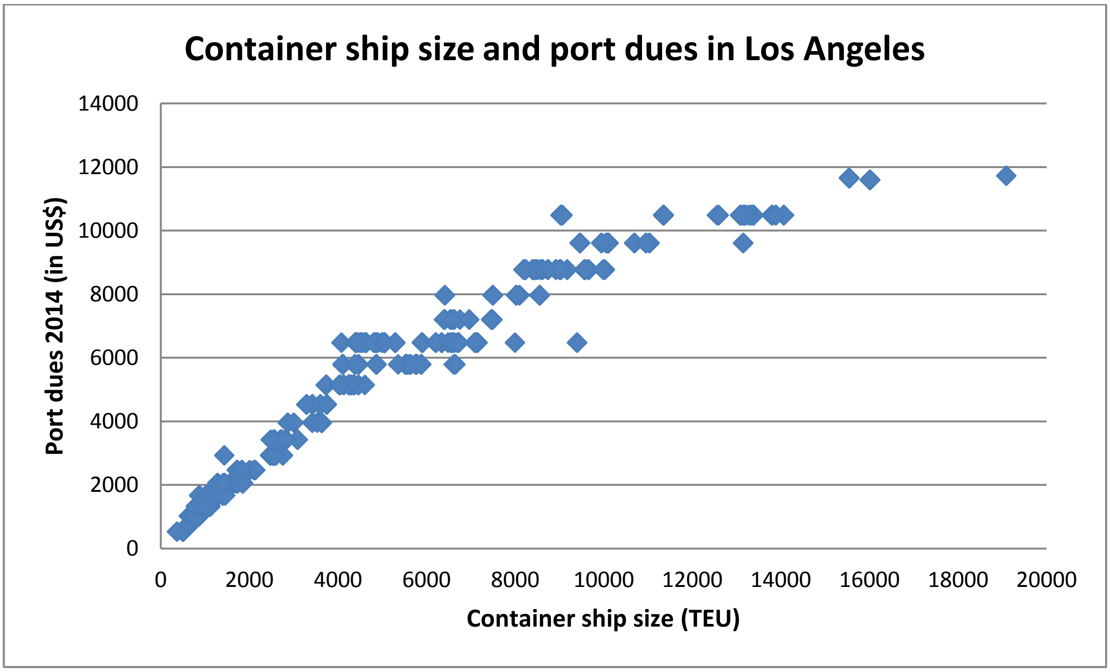
- The 72 19,000 TEU ships have cascading effects, because they will push some of the previous ship capacity on the Far East-North Europe trade lane other trade lanes, including the Far East-Med and Far East-Pacific trade lanes. Some of the ships deployed on these trade lanes will be cascaded to other routes, such as Transatlantic, North-South and South-South routes. This means that the ports in these trade lanes will also be confronted with larger ships than they handled before and larger call sizes leading to higher peaks.

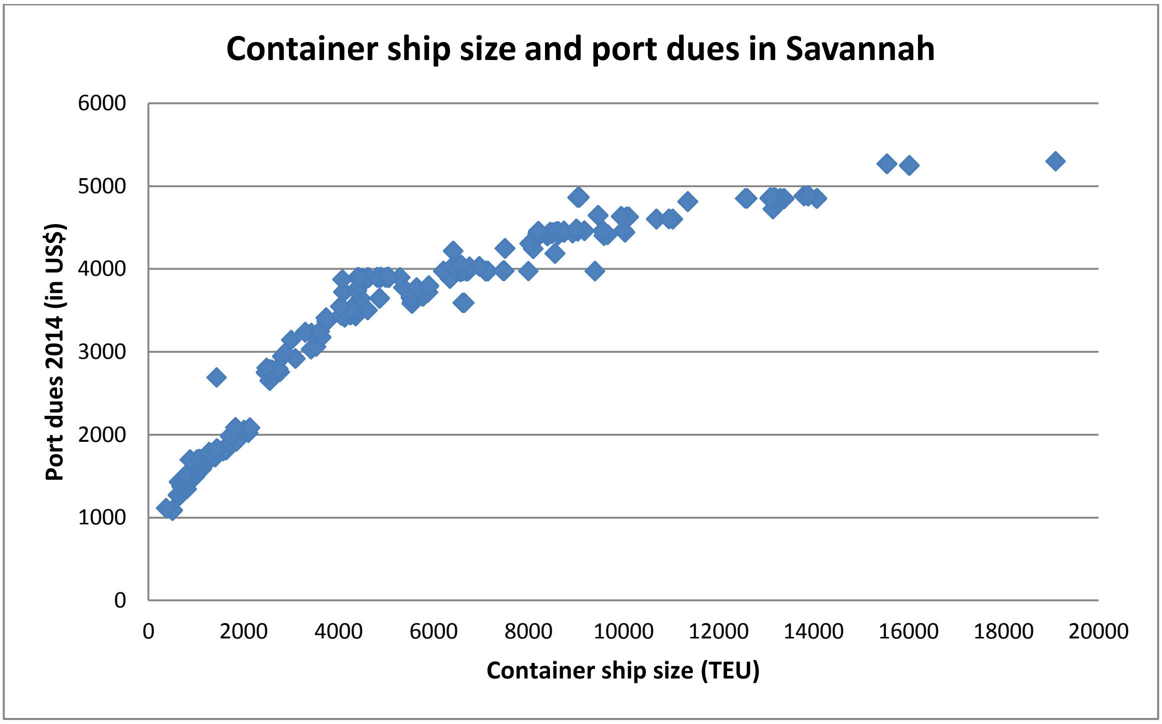
- So we will assume that the ports in other trade lanes also face adjustment costs due to larger ships, but the extent of these adjustments will be different. We assume that the adjustment costs are proportionally related to the size of the flow, so a trade lane with half the TEU flows of Far East-North Europe will be assumed to have half of the adjustment costs.

In addition, we will assume that adjustments will mostly be needed in the ports that have direct intercontinental calls. We include the ports that represent approximately four fifth of the market share on the other East-West trade lanes: 13 ports in the Mediterranean, 4 ports on the West Coast of North America, 5 ports on the East Coast of North America; as well as 5 ports in the Middle East, 6 ports in Latin America and three ports in Oceania. This evidently represents an underestimation as the cascading effects from the larger ships will affect more ports.

Annex 6. Container ship size and port dues in selected ports






Container ship size and port dues in Savannah
Port dues 2014 (in US$)
0
1000
2000
3000
4000
5000
6000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Container ship size (TEU)

Annex 7. List of interviewed people

Christer	Agren	AirClim
Viktor	Allgurén	Port of Gothenburg
Marcus	Andersson	APMT
Jens	Aßmann	Hamburg Chamber of Commerce
Svante	Atlås	SCT Transport AB
Jost	Bergmann	DNV/GL
Jimena	Bernar	Hutchison Europe
Antoine	Beyer	Ifsttar - UR Splott
Lutz	Birke	Hamburg Port Authority
Gunther	Bonz	Eurogate Hamburg
Hans-Georg	Brinkmann	Kühne + Nagel
David	Bull	Thurrock Council
John	Butler	World Shipping Council
Agneta	Carlsson	Swedish Society for Nature Conservation
Jean-Philippe	Casanova	French Maritime Pilots' Federation
Goeffroy	Caude	PIANC
Paolo	Costa	Venice Port Authority
Laurent	Daniel	OECD
Francis	De Ruytter	PSA Europe
Stefan	Eglinger	Urban Transport Administration - City of Gothenburg
Mikael	Eisner	DB Schenker
Ingo	Fehrs	Hamburg Port Authority
Marco	Gaal	Trelleborg
Alexander	Geisler	German Shipbroker's Association
Heinrich	Goller	HHLA Container Terminals GmbH
Arvid	Guthed	Port of Gothenburg
Rolf	Habben Jansen	Hapag-Lloyd
Bertil	Hallman	Trafikverket
Nils	Harnack	China Shipping
Sharon	James	International Transport Workers Federation
Martin	Joerss	McKinsey
Magnus	Kårestedt	Port of Gothenburg
Thanassis	Karlis	Piraeus Port Authority
Dirk	Katteler	Van Oord
Lamia	Kerdjoudj-Belkaid	Feport
Lars	Kjaer	World Shipping Council
Chris	Koch	World Shipping Council
John	Kok	Hutchison Port Holdings
René	Kolman	International Association of Dredging Companies
Amdi	Krogh	Maersk
Ian	Lee	PSA International
Olivier	Lemaire	AIVP
Ulrich	Malchow	Hochschule Bremen
Rémi	Mayet	European Commission DGMOVE
Jens	Meier	Hamburg Port Authority

Thomas	Mendrzik	HHLA CTA Altenwerder GmbH
Antonis	Michail	European Seaports Organisation
Alexis	N'Guessan	Université Félix Houphouët Boigny
Jan	Ninneman	Hanseatic Transport Consultancy
Magnus	Nordfeldt	Port of Gothenburg
Mikael	Nyman	CFL Cargo
Carlos	Pais Montes	Universidade da Coruna
Keld	Pedersson	APM Terminals Gothenburg
Jörg	Pollmann	Hamburg Port Authority
Alexander	Porschke	Nature and Biodiversity Conservation Union
Pascal	Reinards	PSA
Oscar	Rodriguez	Noatum Ports & Maritime
Jens	Roemer	International Federatio of Freight Forwarders Associations
Gerd	Rohden	Hapag-Lloyd AG
Isabelle	Ryckbost	European Seaports Organisation
Bengt	Rydhed	Trafikverket
Yvo	Saanen	TBA
Ulrik	Sanders	Boston Consulting Group
Holger	Scheemann	DHL Freight
Johan P.	Schryver	HJ Schryver & Co
Amélie	Sebek	Egis Conseil
Torben	Seebold	International Transport Workers Federation
Malte	Siegert	Nature and Biodiversity Conservation Union
Jill	Söderwall	Port of Gothenburg
Karin	Strodel	OECD
Claes	Sundmark	Port of Gothenburg
Dimitrios	Theologitis	European Commission DGMOVE
Nicolette	Van der Jagt	CLECAT
Edwin	Van Hassel	University of Antwerp
Patrick	Verhoeven	European Community Shipowners Association
Wolf	von der Mosel	Hamburg Port Authority
John	Wedel	Business Region Göteborg
Sascha	Westermann	Hamburg Port Authority
Ron	Widdows	World Shipping Council
Peter	Wild	G. P. Wild (International) Limited
Anders	Würtzen	Maersk
Jerry	Zellhoefer	

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International Transport Forum

The Impact of Mega-Ships

Container ships have grown incessantly over recent decades due to a continuous search for economies of scale by shipping lines. In the past this has contributed to decreasing maritime transport costs that facilitated global trade. However, the increase in container ship sizes and the speed with which that happens has consequences for the rest of the transport chain. They require infrastructure adaptations and productivity levels that increase costs for port operators, port authorities and other stakeholders in the supply chain. Moreover, mega-ships cause peaks in ports and put a strain on hinterland transports. Has a tipping point been reached, where further increases in ship size result in disproportionally higher port and hinterland costs? What are the impacts of mega-ships for the whole transport chain, and what could be done to optimise the use of mega-ships and mitigate negative impacts?

This study aims to answer these questions through a detailed assessment of the consequences of mega-ships for the different parts of the transport chains: maritime transport, ports, terminals and hinterland transport.

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