The consequences of megaships

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Abstract: In the last decades container ships became larger and larger. Carriers trying to achieve economies of scale by increasing the container ships. Some links in the supply chain face more challenges because of increasing container ships than others. But what are the implications and consequences of so called mega ships? In this paper the consequences for the carrier market, the consequences for the port authorities and the consequences for container terminals will be discussed. A short overview of relevant thoughts and expectations during three phases will be given. The most important limitations to large container ships are technical - and economical aspects.

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Executive summary

Recently the carrier Maersk Line ordered ten 18,000 TEU container ships. Other companies also ordered mega container ships or consider the investment. The trend that container ships increase can be seen in the last decades. But what are the implications of this trend? Who benefits from the larger ships and what are the challenges that need to be faced? The research question in this paper is: *What are the consequences of increasing container ships for the carrier market, port authorities and container terminals?* The total time span of this research is 1985-now. It will be divided into three phases in this research and these phases are based upon maximum ship capacity.

The analysis of the consequences of increasing container ships starts with an analysis of the container shipping market. The liner shipping market is characterised by a couple of aspects. In the last decades globalization became way more important. Companies expanded their operations all across the world. Another aspect that is characteristic for the liner shipping market is the concentration. A lot of shipping liners participate in shipping alliances. Carriers are working together to maximise their position. There are several economic motives behind the formation of alliances. Companies like Maersk or MSC show that it is not necessary to participate in an alliance. These two companies have the highest market share based on total TEU, while not in an alliance. But an alliance could provide the participating companies with an competitive advantage.

In the last couple of decades the container ships became larger. Ever since the introduction of the first container ships the maximum capacity increased. In 1985 the maximum capacity was about 4,500 TEU. This increased during the years till the current maximum of about 15,000 TEU. And Maersk ordered even bigger container ships. There are several incentives behind this increasing ship size. The underlying and most important reason is the concept of economies of scale. Costs do increase with increasing ship size, but the costs per TEU decrease, if more containers are transported. Six perspectives are discussed, but economies of scale is always the underlying concept. These six perspectives are Shipper/customer, (Port) authorities, Technology, Terminal operators, Carriers and Market. Their incentives behind increasing container ships are discussed.

The next step in the analysis are the consequences of increasing ships. The consequences are divided into three parts. First part is the consequences for the carrier market. Second part is the consequences for ports and the third part is the overview of the thoughts and expectations during the three phases. In the carrier market three major trends can be seen. Horizontal integration, vertical integration and the investment in bigger ships. Horizontal integration means that companies that are active in the same link of the supply chain become one. This can be done in an internal or an external way. Various ways to integrate horizontally are discussed. Horizontal integration is partly caused by the increasing ships. The initial investment for a mega ship is very large. It could be that a smaller carrier could not afford this and that it might be necessary to integrate horizontally. Vertical integration is when two links in the supply chain become one. Carriers who invest in container terminals is an often seen form of vertical integration. The trend that ships increase generates advantages and disadvantages for different links in the supply chain. Container terminals form a link that faces disadvantages. Vertical integration between a carrier and a container terminal operator is a way to reduce this disadvantages. The last trend was the investment in bigger ships. In this part other consequences of increasing container ships are discussed. The increase in ships could create a market situation of oversupply. The corresponding decline in freight rates is the

opposite of the carriers' aims. In the last decades a constant balancing between the profitability of carriers and the oversupply situation can be seen on the liner shipping market. Another consequence of increasing ship size is the lowering in sailing frequency. Bigger ships are able to transport more containers at once, so transport is less often necessary, ceteris paribus.

The second part of the third section is about the consequences for ports. This is divided into two subparts, the consequences for port authorities and the consequences for container terminals. Port authorities create the circumstances in which companies can operate the port. The main challenges and consequences port authorities face are the spatial problem and the problem with depth. Larger ships require more space to sail and more space to be handled. Port authorities need to adjust the port to the larger ships. Larger container ships need deeper ports. Port authorities need to deep the port and its channels. The number of container ports that can be handle even the largest container ships is limited. There was some discussion that the container shipping market would go from a multi-port network towards a hub-and-spoke network because of larger ships. This happened, but not as far as expected. The current situation is a combination of both networks. Carriers choose a couple of hub ports to load and unload their containers. The next section is about the consequences for container terminals. This section starts with a description of the container terminal process. The container terminal operators need to make large investments to make sure their terminals are economically viable. Larger container ships need more material such as quay cranes. The terminal operators need to invest in the terminal to keep it efficient. Handling efficiency is crucial with larger ships. When a container ship is in the port, diseconomies of scale will be achieved, and the economies of scale achieved at sea will be lost. If terminals do not operate efficient, the problem of congestion appears. Container terminals need to minimize the time spent in ports, otherwise they are not economically viable. Carriers will choose another terminal to handle the containers.

In the concluding section all consequences are discussed and some point for discussion are mentioned. Some limitations are discussed.

1. Introduction

"This order is a momentous event for the container- shipping industry" Daewoo CEO Nam Sang Tae said in a statement. Nam Sang Tae said this after Maersk Line agreed with Daewoo Shipbuilding & Marine Engineering Co. to buy ten megaships with a capacity of 18,000 TEU. Maersk Line also has the option to buy an additional twenty ships with the same capacity. Other large shipping companies like CMA CGM also consider ordering megaships with capacities over 15,000 TEU. Larger and larger container ships are being used by the shipping companies in order to reach higher profits, due to achieved economies of scale. But what are the implications of this trend for mega ships? Will the situation in the carrier market change? What are the consequences for ports receiving such mega ships? Are ports able to handle such large container ships? What are the consequences for container terminal operators? The trend for ultra large container vessels provides us with a lot of questions. The trend for mega ships has a lot of consequences for the economy as a whole, and for the container market in particular. The trend also affects people working in the port or working in the hinterland of ports. The trend for megaships is relevant to different levels of the economy and influences both direct and indirect a lot people. All these questions will be discussed in this paper.

The trend to construct and use bigger ships is not just one from the last couple of years. For decades the size of container ships increased till the current amounts mentioned. Companies trying to achieve economies of scale by using bigger container ships have done this for many years. The incentives behind the increase in ship size have been investigated before. Earlier research and literature is therefore relevant for this paper. This research will benefit from works from Cullinane and Khanna (2000), Haralambides (2000), Schinas and Papadimitriou (2001), Ircha (2001), Midoro et al. (2005), Notteboom (2006), Akio et al. (2007), Sys et al. (2008), Notteboom and Rodrigue (2009), Arduino and Carrillo Murillo (2010) and others.

1.2 Research question

Since a number of aspects have been mentioned already, it is important to state the leading question of this paper. This research will focus on answering the question: *What are the consequences of increasing container ships for the carrier market, port authorities and container terminals?* Another aspect that will be investigated is how the trend of increasing ship size was evaluated during the years. What were the thoughts about the impact of larger ships?

To answer these questions this paper will first discuss the market for container shipping. Some incentives behind the increasing size of containerships are mentioned. Why do shipping companies like Maersk want such big ships? In the third section the consequences for the carrier market will be discussed. Major trends in the shipping liner market will be highlighted. Next in the third section the consequences of increasing ship size for the ports will be discussed. This part will be divided into the consequences for port authorities and the consequences for container terminals. Final part of the third section will be an overview of the three phases, to discover which where the thoughts about the increasing ship size. Which factors were relevant and what were the thoughts about the economically and technically viability of container ships. Fourth section will contain the conclusions.

This research will consist of the analysis of certain time phases. The time span for the rest of the research will be the last thirty years. This period will be divided into three phases in the rest of the research:

• Phase one describes the period 1984-1995. In this period the maximum capacity was ≤ 4500 TEU.
• Phase two describes the period 1995-2006. In this period the maximum capacity was 4500-10000 TEU
• Phase three describes the period 2006-now. In this period the maximum capacity was ≥ 10000 TEU

2. The containership market

This second section will consist of two parts. First part is a short analysis of the market of container ships. A brief overview of the relevant companies and the market situation will be given. Second part of this section will discuss the development of container ships through the years and the incentives behind the trend of increasing container ships.

2.1 Market analysis

The market for container transport is more than just the shipping from port to port. Various companies are involved in transferring the container from some place to another. The supply chain consitst of seven relevant parties (see Appendix, Figure A1). It could be that steps in the supply chain are vertically intergrated. In that case there are less relevant parties. The shipper wants to send goods elsewhere via a container. A transportation company transports the container towards the port. The container is handled by a container terminal, and placed on a container ship owned by a shipping liner. This shipping liner transports the container towards another port, where container terminal operator two takes the container from the ship. Another transportation company brings the container towards its final destination, the receiver. This can be done in various ways: by inland shipping, by rail or by road for example. The relevant part of the supply chain for this section is part four, the shipping liners. In this section the market of shipping liners will be discussed.

A trend that is visible in the market of shipping liners is the globalization. Carriers expanded their operations all across the world (Notteboom, 2004). A common aspect can be found in the trade flows and the activities of carriers. Carriers are active on the trade flow areas. The most important carrier routes are Trans Atlantic, Trans Pacific and Europe-Far East (see Figure A2, Appendix; Kaluza et al. 2010). A remark that should be made is that this figure shows all trajectories of ships larger than 10,000 GT, so not only containerships. The results would however have been comparable if only containerships would have been considered. All carriers are active on many routes, in order to transport as much containers as possible. Most carriers have some fixed lines they serve. In order to get as much market share of total transportation carriers try to get a competitive advantage. This will be discussed later more extensively.

The market for container shipping is characterised by high concentrations. Global alliances of large shipping companies are very common in this market. There are a couple of large alliances at this moment.

Tabel 1: Largest alliance in container shipping market

Alliance	**Members**
Grand Alliance (GA)	Hapag-Llyod, Orient Overseas Container Line (OOCL), Nippon Yusen Kaisha (NYK) and MISC Berhad
Independent Carriers Alliance (ICA)	CMA CGM, Hanjin Shipping, Compañia Sudamericana de Vapores (CSAV) and ZIM
CKYH Alliance	COSCON, Hanjin Shipping, “K”Line and Yang Ming Line (YML)
New World Alliance (NWA)	APL, MOL and Hyundai Merchant Marine (HMM)

Source: APL (2005)

There are also some companies that do not participate in a global alliance, like A.P. Moller - Maersk Group (APM-Maersk), Mediterranean Shipping Company (MSC), China Shipping Container Lines (CSCL) and Hamburg Süd (APL, 2005). These alliances were established to provide better competitive positions against other shipping liners (Midoro and Pitto, 2000). Several economic factors influenced the decision to form alliances. Risk and investment sharing, economies of scale, a capability to increase service frequencies, wider geographical scope, possibility to perform vessel planning and co-ordination on a global scale and entry in new markets are the base for the shipping alliances (Midoro and Pitto, 2000). These factors provide an economic base for any alliance of companies (Bleeke and Ernst, 1995). Midoro and Pitto (2000) described also two relatively new aspects that should be taken into account as a factor for the shipping alliances. First one is the globalization of world markets and the second is the protracted poor profitability of most carriers. Dicken (1992) described two factors that underline the globalization trend. The first is the decline in barriers to the free flow of goods, services and capitals and the second factor is the huge development in communications, information and transportation technologies all over the world. Midoro and Pitto wrote their research already in 2000, and since then the globalization has increased even stronger compared to the 1990s. Therefore, the globalization argument did become an even more important factor in the shipping alliances in the last ten years.

Slack et al. (2002) described, using a broad-brush survey, which consequences the restructering of the carrier market had. Slack et al. mention already some restrictions to their research, but still their research provides useful observations to answer questions about the effect of alliances. Their main conclusions are: *"The growth in the number of services and in the intensification of service frequency over the decade has been confirmed. Numbers of vessels have increased, but more significant has been the increase in vessel size. Individual carriers are serving more ports than ever. On the other hand, the total number of ports served has remained remarkably stable"*(Stack et al., 2002). But do these alliances really provide the included parties with an advantage compared to companies that do not participate in an alliance? If the twenty largest shipping liners are compared, based on data of AXS Alphaliner (2011) and a comparison is made between the alliances, the following can be seen (Table 2).

If the alliances are compared to the two largest independent shipping liners in the world, APM Maersk and MSC, the alliances in general do not perform better than independent companies (see: Table 2 and Appendix, Table A1; AXS Alphaliner, 2011). Another aspect is that the shipping alliances did shown to be unstable from time to time. It would however become to extended to describe the question whether or not joining a shipping alliance is the optimal solution for a shipping liner, so the research will not further focus on this.

Table 2: Market share per alliance/company

Alliance/Company	**Market share (%)**
GA	9.2
ICA	17.5
CKYH Alliance	11.6
NWA	8.5
APM Maersk	14.9
MSC	12.9

Source: AXS Alphaliner (2011)

2.2 Container ship development

Before the research will continue with the development of containerships through the years, a fleet analysis will be done first to provide a clear overview what kind of container ships actually are being used these days. After this fleet analysis, the development and the incentives behind these developments will be discussed.

At this moment the large majority of ships is smaller than 10000 TEU. There are only 75 container ships with a capacity of 10000 TEU or more. This is just 2,67% of the total ships. If this is compared to the amount of ships with a capacity less than 5000 TEU an huge difference can be seen. At this moment 70,3% of all the container ships that are being used has a capacity less than 5000 TEU. There are also a lot of ships with a capacity between 5000 and 7999 TEU, namely 491 or 17,5% of total ships (Containerisation International, 2011). A graphical illustration of this data is given in figure 1 (see: Appendix, Figure A3). The trend for megaships is present and clear, but it should be noticed that only a very small fraction of the total fleet consists of megaships (10000 TEU or bigger). The average capacity of a containership, according to the Containerisation International Data (2011) ≈ 4100 TEU.

If the orders for new container ships, completed in the period 2011-2015, are considered however, the trend for bigger ships is more present than in the past. The total weighted average capacity of all ordered containerships for the period 2011-2015 ≈ 8530 TEU (Containerisation International, 2011). As can be seen in Table A2 in the Appendix, most of the nineteen largest shipping liners ordered large containerships. Hapag-Lloyd, Hanjin Shipping, OOCL and ZIM have an weighted average capacity of more than 10,000 TEU for their ordered ships. Other shipping liners like CMA CGM and MSC are very close to this 10,000 TEU border. Exact capacities of the ordered ships are not included in this research, but the weighted average capacities give a reliable indication. The average size of containerships will rise in the next couple of years. Larger containerships have been ordered and will be introduced in the next couple of years. The maximum capacity of containerships will increase, given the now available order book, to 18,000 TEU in 2014.

As mentioned before, the trend for megaships is definately present. Ever since the introduction of the first container vessels, the ships increased in size. In 1951 the first purpose-built container vessels became operational. These first container ships were constructed by renovating a surplus of an old T2 tanker after World War II. The container ships operated in Denmark and also between Seattle and Alaska (Med Truck International, 2009). During the 1960s the size of the ships increased steadily, and this trend continued in the 1970s and 1980s. From mid-1980s till mid-1990s the average capacity grew steadily, while the maximum capacity remained relatively stable around 4500 TEU. After 1995, a rapid growth in maximum size of container ships can bee seen. Due to the introduction of the post-Panamax concept (pioneerd by APL), the maximum capacity grew till about 7000 TEU around 2000. In the period 2000-2005 the container ships kept increasing in both average size and maximum capacity. In 2006 and 2007 APM Maersk introduced eight of the largest container ships used untill now. These ships have a capacity of 15550 TEU nominal (Maersk Line, 2011). Due to the introduction of these megaships, there was a strong increase in size of container ships (Arduino and Carrillo Murillo 2010). In general the conclusion can be that the trend is that container ships increase in average size and especially increase in maximum capacity. A graphical illustration of the size of container ships in the last thirty years is given in the appendix (see: Appendix, Figure A4; Arduino and Carrillo Murillo, 2010).

But what are the incentives behind this increasing container ship size? What are the benefits of such a large containership? Before the decline in costs can be discussed, first the relevant costs need to be explained. Wijnolst and Wergeland (2009) distinguish four main cost categories in the running of ships:

1) Capital costs (depreciation; interest payments)
2) Operating costs (manning costs; maintenance and repairs; stores, supplies and lubricating oils; insurance costs; management overhead)
3) Voyage costs (variable costs associated with actual sailing such as bunkers, port charges, canal dues)
4) Cargo handling costs (costs for loading and discharging ship's cargo)

A more specific cost structure is made by Chen and Zhang (2008). The graphical illustration of their cost structure can be found in the Appendix, Figure A5. Most companies strive to reducing costs as much as possible. Reducing costs can be done in various ways. A reduction in average costs is commonly used. Also in container shipping this is relevant. The underlying economic concept behind increasing container ship size is the concept of economies of scale. Economies of scale mean that average costs decline with increasing output. Classic economies of scale relate to the effect on average costs of production of different rates of output, per unit of time, of a given commodity, when all possible adaptations have been carried out to make production at each scale as efficient as possible (Silberston, 1972). Economies of scale can be showed graphically by the scale curve. The scale curve shows the decline in costs per unit as output increases. Kasner and De Cicco (1946) discussed the mathematical theory behind the scale curve, but since this is too detailed, this research will not further focus on this.

If this theoretical concept of economies of scale is applied to the container shipping market, the following can be seen. Mentioned earlier, economies of scale are the underlying incentive for ship size increase. In container shipping the implication is that the costs per TEU carried decline when the carried number of containers increases. Cullinane and Khanna (1999) showed in their research that indeed economies of scale could be achieved by increasing the ship size. Based on data by Fairplay (1996) Cullinane and Khanna found that economies of scale could be achieved until a capacity of 8000 TEU. Different routes, and therefore distances, were also included in the analysis, to discover whether different distances affect the economies of scale that could be achieved. But on all three compared routes (Trans Atlantic, Trans Pacific and Europe-Far East) the trend was the same. As can be seen in Figure A6 in the appendix, on all three routes economies of scale can be achieved. The further the distance, the larger the economies of scale are. It should be noted that if additional feeder, transhipment and landside distribution costs are taken into account, the unit cost per TEU could increase again. This is illustrated by Sys et al. (2008). But in this section only the shipping liners are considered. The results of the study of Cullinane and Khanna suggest an optimal ship size of 8000 TEU. Cullinane and Khanna indicate however that larger ships could be economically viable, but the port productivity should increase first.

There are also some scientists who are more sceptical about achieving economies of scale. Stopford is a well known one. Stopford says that economies of scale can be achieved by increasing ship size, but only with a capacity up to and including 5000 TEU. If ships increase further, economies of scale diminish very rapidly. The economies of scale from operating costs, capital costs and bunker costs are very low (Stopford, 2002). But a majority of research shows that economies of scale can be achieved by increasing ship size. Something that should be considered however is diseconomies of scale. The costs for handling such large containerships in ports increase with increasing ship size. The time to handle all the extra containers and the extra work necessary create extra handling costs. But in general it is assumed that the economies of scale enjoyed at sea outweigh the diseconomies of scale suffered in ports.

There are also other factors influencing the increase in ship size, next to economies of scale. Economies of scale are however most of the time the underlying factor. Sys et al. (2008) discuss factors that influence the increase ship capacities. The six perspectives are: Shipper/customer, (Port) authorities, Technology, Terminal operators, Carriers and Market (see Appendix, Figure A7).[1] The most relevant factors will be discussed now.

• The Shipper/customer. The demand for shipping of goods rises. More and more goods need to be shipped. A second argument from this perspective is the global accounts. More and more globalization takes place.

• (Port) authorities. The first argument is the ongoing deregulation. Second is the development of mega ports. Ports try to increase in size and in throughput, in an attempt to beat their competitors. These larger ports can handle and attract larger container ships. An example of this increase in port size is Maasvlakte II. Maasvlakte II is a large land acquisition project in Rotterdam, to expand the port area with around 20%. Third aspect is the development of mega ports, and the development of port access. Ports try to attract more and larger ships and make it easier to access the port, by for example deepening the port. In this way, also ships with bigger drafts can enter the port. Ports and their authorities compete with each other to attract as many and as large ships as possible, and therefore create the facilities these ships need.

• Technology. To start, the technical limitations have not been reached yet. And because of technological development, these technical possibilities increase each time. Larger and larger ships are technically possible. Second argument is the increased implementation of IT-applications. Technologies like RFID (Radio Frequency Identification tags) make it easier to handle containers. More containers can be processed in a certain amount of time.

• Terminal operators. The most important argument from this perspective is the ability of container terminals to physically berth such units. Container terminals increase their handling capacity and are able to process more containers within an acceptable time frame.

• Carriers. Permanent strive for cost cutting is the first argument. Carriers, like almost all companies, try to make a profit. Lowering costs can increase the net profit. Second argument for increase in ship size, is the formation of alliances. The largest alliances have been discussed before, but the formation of such alliances makes larger ships more attractive and economically viable. Third argument is the search for a competitive advantage. Carriers are always trying to perform better than their competitors. A megaship can be a source of such a competitive advantage.

[1] These six perspectives are based upon research by Sys et al. (2008)

• Market. First argument is the general increase in the container shipping market. The volumes increased rapidly during the last decade. The increase in trade with Asia, and the corresponding shipping necessary, provided a lot of containers to be shipped. Last relevant factor to be discussed is the containerisation trend. More and more goods are transported in containers. Larger ships can handle this increase in supply.

3. Consequences of increasing container ships

In this section the consequences of the increasing container ship size will be discussed. The consequences will be divided into two aspects. The consequences for the carrier market and the consequences for ports will be discussed. After these general consequences have been discussed, an analysis will be done, to explain the most relevant thoughts and expectations about consequences of increasing ship size during the years. In the analysis of the consequences the time span used will be the one indicated in the introduction. Three phases, starting in the mid-1980s and continuing till now.

3.1 Consequences carrier market

In the last decades three major trends can be separated in the liner shipping market. These three trends are horizontal integration, vertical integration and investment in bigger vessels. These trend are of course related, and do sometimes overlap with each other. These three market trends will be discussed in order to explain the consequences of increasing ship size for the entire liner shipping market. It is important to first have a general overview of major trends in the liner shipping market. In amongst Midoro et al. (2005) and Cariou (2008) investigated the liner shipping market and the strategies used by shipping liners.

First one to be discussed is horizontal integration. Horizontal integration can be described as the combining or cooperation of companies or institutions. It is crucial that these companies are active in the same link of the supply chain. Horizontal integration is done to become larger and more powerful companies. Horizontal integration can be done in two various ways. It can be done in an internal or external way. Chartering and direct investment in new vessels are mostly used to grow internally. The external growth is mostly done by mergers and acquisitions or by means of the formation of strategic alliances (Cariou, 2008). Both ways are obviously non-exclusive, and in practice shipping liners did use both methods in the last decades. All four mentioned methods will be explained briefly. Chartering is the use or the providing of ships to/from another company. The other company operates the ships for the chartering company. Direct investment in new vessels is clear. Shipping liners invest in new container ships in order to become larger and to increase gains. More ships means more supply, more possibilities to operate and serve the shippers. Mergers is when two or more companies want to cooperate, and they merge together to continue as one company. An important reason for mergers is the assumption of achieved of economies of scale and scope (Given, 1996). This will however not be discussed further. Mergers are most of the time ‘friendly’ and with agreement of both parties. Acquisitions however are mostly hostile. One company or a consortium of companies buys the other company and becomes the new owner of the company. This new company will be integrated into the buying company, just like with mergers. And finally, strategic alliances. This has been discussed before in section two. But why do companies want to integrate horizontally? Horizontal integration is simply said done to become larger. Companies try to improve their competitive position by becoming larger. Larger companies or larger alliances are more powerful compared to smaller companies. Larger companies have more possibilities to for example invest in mega container ships. The formation of alliances or the increase in companies is done to increase the market power and market position of the involved companies. Economies of scale are also an important aspect in horizontal integration. The companies try to achieve these economies of scale by horizontal integration. The trend for horizontal integration can be seen throughout the entire time span of this paper. Especially during the years 1990-now, but also before

1990. Horizontal integration is related with the globalization trend. Activities were expended on a more worldwide scale and horizontal integration facilitated this extension. Mergers and acquisitions were (and are) a very good way to operate more activities around the world. The question now is, what is the relation between horizontal integration and the trend of increasing container ships. The building price of a larger ship is obviously higher than the price for a smaller container ship. The relative price, looking at price and capacity, is lower for bigger ships (Cariou, 2008). But the absolute initial investment that companies need to make in order to get a large container ship is higher. The 18,000 TEU ships Maersk ordered cost for example $300,000,000 ($5.4 billion/18; Kyunghee and Morris, 2011). These ships are of course top-of-the-line, but large container ships are in general very expensive. It could be a problem for a small company to pay such an amount of money for container ships. To be able to buy larger ships, companies integrated horizontally. So horizontal integration is partly caused by the trend for increasing container ships.

The second major trend in the shipping liner market was vertical integration. Vertical integration is when multiple links in the supply chain become ‘one’. An example in the carrier market is a carrier which starts operating its own container terminal. Vertical integration started in the mid 1980s. Before then a lot of companies involved were state-owned. From the mid 1980s, governmental institutions started the beginning of port privatization all over the world. The first stevedoring companies decided to invest in a terminal facility. During the late 1980s globalization become more important. More companies expended their operations abroad. In the 1990s the globalization trend became even stronger. More investments in terminals and other facilities were done. During the years the most common form of vertical integration in the container shipping market was the integration of shipping liners and container terminal operators. Ever since the 1960s carriers have been investing in terminal facilities. During the 1960s and 1970s these investments were driven by the need for standardized facilities. Especially during the 1980s and 1990s these investments were based on vertical integration. During these years the investments were done to get control over the supply chain. And since then the carriers invest in terminal to keep and defend assets deployed on the main routes (Midoro et al., 2005). Carriers can have various reasons for investing in container terminals. It could be that a carrier thinks it can operate the container terminal more efficient, and therefore reduce costs in the long run. Not only terminal efficiency could be an argument, also supply chain efficiency can be an incentive. Shippers prefer the fastest transportation towards the receiver. If the carrier thinks it could handle the containers more efficient than the current terminal operator, it could invest in an own terminal. This could increase the total supply chain efficiency. Another argument could be that a carrier prefers to have a reliable and certain terminal. If a carrier has its own terminal, it has the certainty of capacity and availability. Carriers could also invest in terminals as a strategic investment.

But why does vertical integration take place? Casson (1986) provides situations which favour vertical integration. Who benefits from vertical integration? And what is the influence of the trend for increasing container ships on vertical integration? Which supply chain links benefit from increasing ship size will be discussed first, and then the consequences of increasing ships for vertical integration will be discussed. The most clear link in the supply chain with an advantage of increasing container ships is the carrier link. Carriers benefit from the achieved economies of scale. But container terminal operators cannot benefit from increasing ship size. Container terminal operators need to make large investments in material and capacity in order to handle the larger container ships. This will be discussed more extensively in the next section. But both container terminal operators in the supply chain do face disadvantages of increasing ship size. Transportation firms transporting the containers to the hinterland or to the port will not face many advantages or disadvantages. These companies can benefit more, because more containers need to be transported, but extra material is required for this transport. Whether transportation firms benefit from the increase in ship size is difficult to state. But both the beginning and the end of the supply chain, the shipper and the receiver benefit from increasing ship size. Larger ships means lower costs of transshipment. This is a clear advantage of increasing ship size for these parts of the supply chain. There is a relation between the most common form of vertical integration, between carriers and container terminal operators, and on the other hand the link in the supply chain which faces disadvantages of increasing ship size. Carriers, which benefit most from the increasing container ships, try to reduce disadvantages in the supply chain by vertically integrating the container terminal operations. This is an important consequence of increasing ship size. More vertical integration, especially between carriers and terminal operators.

The third trend on the carrier market was the investment in mega container ships. Since this trend is the subject of this paper, no further explanation will be given here. This part will discuss the consequences of the investments in bigger container ships that are not discussed in the horizontal- or vertical integration part. In an economic market there is supply and demand. At the ‘point’ supply and demand meet, there is the equilibrium. A certain price and quantity are created. If this is applied to the container shipping market, the following can be seen. Because of the increase in ship size, the supply of container transport goes up. More capacity is available and therefore the freight rates will lower, ceteris paribus. Consequences of increasing ship size are the decline in freight rates and the increase in supply, ceteris paribus. The investments in mega container ships creates sort of a vicious circle. A lot of carriers invest in mega ships, and they compete for the available cargo to fill these mega ships. This is necessary to achieve the economies of scale. However, freight rates will decline, and thus will the return on investment. This will lower the profit. To maintain the competitive advantage and the profits, carriers try to achieve cost reductions. And these cost reductions lead us back towards the investments in mega container ships (Wijnolst and Wergeland, 2009). What can actually be seen in the container shipping market in the last decades, is a constant balancing between overcapacity, and a corresponding decline in freight rates, and on the other side the profitability of shipping liners. Carriers want to maximize their profit, and therefore prefer maximum capacity for their own company. But if every carrier strives for maximum capacity for its own company, oversupply on the entire market will be the final result. Oversupply will push freight rates down. And profits will decline, so exactly the opposite result is achieved. As mentioned before, the market equilibrium is where supply and demand meet. In the container shipping market demand fluctuates. The worldwide economy is an important aspect that determines the demand for container shipping. During the recent economic crisis the worldwide container shipping declined (Notteboom et al., 2010). In order to prevent the situation of oversupply shipping liners needed to adjust the supply. In general shipping liners need to carefully determine which ships to deploy on which routes. Determining where to operate a mega ship is extremely important. In order to achieve the necessary economies of scale, the ship must be used in an optimal situation. That why mega container ships are now only deployed on the main trade flows. The economies of scale can be achieved here. This high density trade is required to fully use the capacity of the largest container vessels. Of course carriers would like a yearly growth in container transport. This provides both certainty and opportunities for liners. This is however not always the actual situation. It might be that because of the increasing ship size carriers are not able to load the entire ship, but only 90% for example. This is economically less attractive for a shipping liner compared to a 100% loaded ship. Therefore the carrier will lower its sailing frequency. This is another consequence for the carrier market, the lowering in sailing frequency (Chaug-Ing and Yu-Ping, 2007).

3.2 Consequences ports

Now that the consequences for the carrier market have been showed, the consequences for ports will be discussed now. In amongst Schinas and Papadimitriou (2001) discuss consequences for ports. It is impossible to indicate the consequences for 'the port'. A lot of different parties are involved in the container market in ports. The consequences that will be discussed relate to two involved parties, namely the port authority and the container terminal operators. The transport towards the hinterland will not be discussed by itself, since the consequences for hinterland transport have similarities with the consequences for the terminal operator. Relevant consequences for hinterland transport will be incorporated.

This section will start with the consequences for port authorities. Port authorities are often governmental or quasi-governmental institutions who own the port. Port authorities are responsible for providing a port that can be operated. Companies like terminal operators buy or rent land from the port authorities to operate their terminals. But the port authorities build and maintain the port and its waterways. Port authorities create the circumstances for companies to operate. Port authorities try to make the port as attractive as possible, in order to attract companies towards the port. Port authorities need to take a lot of interests into account in their decisions. The trend for mega ships influences the decisions the port authority takes. The larger the incoming container ships are, the bigger the challenge for a port to handle the container ship. The first challenge for the port in general is the space problem. The largest container ships have a length up to nearly 400 meters (Maersk Line, 2011). Not all container vessels are this big, but the largest ships are this long. These very long containerships need to be able to enter the port and reach the container terminal. Port authorities need to build the port in such a way that even these mega ships are able to enter the port. Over the years container ships became larger. A first consequence of this trend is that port authorities need to adjust to this trend by building the port broader. More space for ships to enter the port and to move through the port.

But this is more complicated than it seems. A lot of ports face problems with a lack of space (Notteboom and Winkelmans, 2001). The port of Rotterdam is a very good example of this explained situation. Rotterdam has a very competitive port due to several factors such as natural position. The fairway of the port of Rotterdam is so deep that even the largest container ships with the biggest drafts are able to enter the port. The current terminals were able to handle even the largest container ships. But in order to handle the growth in container transport and increasing ship size, the total capacity of the port needed to be expanded. This requires space. But mentioned already, the port of Rotterdam had to deal with the lack of space. To solve this problem the Rotterdam Port Authority (RPA) decided to build the 'Tweede Maasvlakte'. It started in 2008 (NOS, 2008). The major part of this project is meant for container transport. A growth in both total container transport as a growth in container ship size is expected, and the RPA adjusts the port in this way.

Another aspect that port authorities need to consider is the depth of the port. Larger container ships with more containers do have a larger draft. The ships Maersk Line ordered recently, with a capacity of 18,000 TEU, have a draft of approximately 17 meters. An often forgotten aspect is the air draft of container ships. Air draft of a container ship is the distance between the water surface and the highest point of the ship (van Ham, 2005). Ports with for example bridges need to take this into account. With the increase in capacity of container ships, an increase in the draft is visible as well. Since only a limited number of ports can handle container ships with such drafts, the thoughts were that less ports would be served. The maritime network, and more specifical the market for container shipping contains two different types of networks. Both the hub-and-spoke network as the multi-port calling network are discussed. The main lines can be characterized by a hub-and-spoke market situation. In among Haralambides (2000) and Chaug-Ing and Yu-Ping (2007) describe this market situation. In a maritime hub-and-spoke network, major ports are usually selected as hub ports based on their location and the demands of freight shipping, while the other ports serve as feeder ports, i.e. spoke ports. The largest mega container ships are used on the main lines, Trans Atlantic, Trans Pacific and Europe-Far East, to provide services among hub ports. Smaller feeder vessels are on the other hand used on feeder lines to transport containers between the hub port and its feeder ports (Chaug-Ing and Yu-Ping, 2007). Multi-port calling networks are also present. More ports in a certain area are called, and part of the containers is delivered in each port. The trend visible is that the largest container ships are active on the main transport lines, since the most economies of scale can be achieved here. The trend in the last decades has been to increase the ship size, as mentioned before. But the question whether this increase in ship size leads to more concentration into the hub ports has no clear answer. The hub-and-spoke network becomes more important, but the situation has also characteristics of a multi-port calling network. The carriers choose a couple of hub ports to load and unload their containers. So it is a combination of a hub-and-spoke network and a multi-port calling network. In the last decades the container shipping market moved from a multi-port calling network more towards a hub-and-spoke network. But the market has characteristics of both networks. A reason for increased interest in hub and spoke transhipment service networks relates to the trend towards deployment of bigger ships (Baird, 2006). Other causal factors will not be discussed here, since it is not relevant for this research. Imai et al. (2009) discuss some complications related to on the one hand, the multi-port calling networks and on the other hand, the hub-and-spoke networks. Their research compared different ship sizes and different networks. Their research showed that multi-port calling networks are superior to the hub-and-spoke network in terms of container management costs. But in general the movement towards the hub-and-spoke network is a second consequence of the increasing ship size for the ports.

Now that the consequences for the port authorities have been discussed, the next section will explain the consequences for the container terminals and their operators. The impact of increasing container ships is larger for container terminals compared to port authorities. Container terminal operators need to make large investments in order to keep their terminals economically viable. To handle even the largest container ships terminal operators need to constantly invest in their equipment to load/unload the container vessels. To be able to indicate the consequences of mega ships for container terminal operators, it is important to first illustrate the processes at a container terminal. Ex post, the consequences of increasing container ship size will be given for container terminals.

The description of the container terminal processes is based on research by Vis and de Koster (2003). A graphical illustration of this process can be seen in the Appendix, Figure A8. When a large container ship arrives at a container terminal, the berth should be determined. In a research by Imai et al. (1997) it is studied how to allocate berths to container ships while optimising the berth utilisation. Different berth allocation options are available. Minimising the sum of port staying times, by mooring the ships according to the first come first served principle. Or ships could be moored closest by the area in the stack in which most containers for this ship are located. Once the ship has arrived at its quay, the loading and unloading can start. Quay Cranes (QC) are used to load and unload the containers in- and out of the ship. A possible problem with loading a container ship is the stowage problem. According to Wilson and Roach (2000) the size of the container stowage problem depends upon the capacity of the ship and the demand and supply of containers at each port. The container stowage problem will thus be a bigger problem for the mega ships. The QC lifts the containers off of the ship and puts the containers on a vehicle. Some container terminals like the ECT Euromax terminal in Rotterdam use automated guided vehicles, while other terminals use manned vehicles to transport the containers from the quay to the stacks. Straddle carriers or other stack cranes place the containers onto the stack. Stacking can be done on a chassis and on the ground. Because of limited storage space, most container terminals stack their containers on the ground. The stack is a very important stage in the container terminal process. Both the container movements towards and from the ship have their origin/destination at the stack. Therefore, efficient stacking is necessary to ensure that the remaining operations can be carried out effectively (Vis and de Koster, 2003). Last stage of the container handling process of the terminal is the transportation of the container from the stack to the hinterland connections. This could be for example barge or road transport. These transportation modes distribute the containers to the hinterland, and the final destination of the container. The transportation to the hinterland is the end of the process of the container handling by the container terminal. The entire process is a quite complex operation. Different aspects need to be taken into account in determining the optimal strategy.

The increase in ship size is one of those aspects that need to be taken into account. All the different stages in the container handling process through the container terminal need to be adjusted in order to receive the largest container ships. During the decades, more quay cranes were used to load and unload the ships. But it is not just a matter of deploying more cranes. First there are regulations, which also influence the number of cranes by requiring a certain safety distance in between two quay cranes. Secondly there is an optimal number of cranes deployed and it depends on variables. A research by Lee et al. (2008) focuses on the Quay Crane Scheduling with Non-Interference constraints Problem (QCSNIP), which can be used to determine the optimal number of quay cranes active. The number of cranes deployed did increase because of the increasing ship size, but only to a very limited level. To load and unload the largest container ships a maximum of six or seven cranes is used. There are not much consequences for this part of the container terminal process. But from phase three, the stacking, till phase five, the transport towards the hinterland, the process is influenced more by the increase in ship size. More vehicles are necessary and more space is required to handle the extra containers. Also more transport to the hinterland is necessary. Therefore, more facilities like rail or roads need to be constructed. Terminal operators need to make heavy investments in their terminals to handle the largest container ships.

All this investments are meant to make the container terminal as attractive as possible for carriers. The attractiveness of a container terminal depends for a large part on the efficiency of container handling. Ports constantly compete with each other to handle containers the fastest and efficient as possible, in order to attract large container ships. Two widely applied approaches to measure port efficiency are data envelopment analysis (DEA) and stochastic frontier analysis (SFA). Applications of DEA to the port sector include Roll and Hayuth (1993), Martinez-Budria et al (1999), Tongzon (2001),Barros and Athanassiou (2004) and Cullinane et al (2005b, a, 2004a). Example applications of SFA to port data include Liu (1995), Notteboom et al (2000) and Cullinane and Song (2003). This competition to become 'the most efficient' port is done to attract more container transport (Wang, 2006). The more efficient a container terminal operates, the more container transport it is likely to attract, ceteris paribus. The efficiency is also very relevant for the mega ship trend. Every carrier prefers to have his container ship loaded and unloaded as fast and simple as possible. Because of the increasing ship size, more containers need to be handled at the container terminal. The more efficient a container terminal operates, the better the terminal is able to handle all this extra containers. Chen (1999) described various storage strategies in order to increase the efficiency of stacking. Stacking is just one part, although an important one, of the container handling process in the terminal. But in general, ports need to strive towards maximum efficiency in all parts of their process.

If a container terminal would not operate efficient, the problem of congestion appears. The mega container vessels would bring too many containers to the port and the terminal. Especially the hinterland connections would not be able to handle all this containers. The container terminal would get less attractive, if containers cannot be handled efficiently. Carriers will choose other terminals. If container terminals and port authorities would not invest in extra capacity, congestion in ports could be a consequence of the increasing ships. However, most port authorities and terminal operators invest a lot in extra container handling capacity by creating new terminals. If too much new terminals are created, the problem of overcapacity could occur. This will not be discussed further, but in general it could be concluded, that port authorities and terminal operators need to balance between overcapacity and congestion problems. The efficiency of a container terminal is very important for the time a container ship has to spend in the port. The more efficient a container terminal can operate, the shorter the time is the ship needs to stay in the port. Time is a crucial aspect in container shipping. Notteboom (2006) indicates that the time management in container shipping is one of the key elements in the liner services. Liners and other actors from the supply chain face the important challenge of managing the time factor in the design and operation of liner services. Waiting time is very expensive for carriers. Carriers prefer the port turnaround time to be as low as possible. A consequence of larger container vessels is the increase in time spent in the port. Since the mega container ships reduce the number of ports in order to achieve economies of scale, the load and unload time in the ports will increase. More containers need to be loaded and unloaded in fewer ports. Robinson (1978) however found that in the port of Hong Kong, larger vessels could be handled even faster than smaller ships. His explanation was that with increasing ship size, better material such as cranes, became operational, and therefore larger ships could be loaded and unloaded quicker. This research by Robinson is quite dated, but is still relevant today, although circumstances differ today compared to 1978. Also today technological developments constantly become operational. Quay cranes are developed and improved, just like all the other material. So larger ships, do need more time in ports, but technological development is capable of (partly) reducing this extra time. This reduce in port time is important, because as long as the container ships are in the port, they will not generate income for the carriers. The economies of scale achieved at sea, will partly be lost in ports (in amongst: Schinas and Papadimitriou, 2001).

3.3 Thoughts and expectations

Now that the consequences for the carrier market, the port authority, the container terminal and the container terminal operator have been discussed, this paper will continue with an analysis of the container ships throughout the time. What were the thoughts and the experiences about the increasing container ships?

Phase III

The first phase to be discussed is phase III. This is done because it is the most recent and therefore relevant phase. The mega ships discussed in the paper are the ships which can be found in this phase and time era. This last phase describes the period 2006-now, with largest container ships. These container ships have a capacity of 10,000 TEU or more. Ever since the introduction of the 10,000 TEU ships by Maersk in 2006, the development of even larger ships continued. Technical developments made the current mega ships possible. There are some technical -, some economical - and some environmental aspect that are considered in the strive for bigger ships. Technically spoken, Malacca-max ships are possible. These Malacca-max ships, named after the Strait of Malacca, can have a draught of 21 meters. Taking into account all the relevant technical factors, STX has developed the technology to build a 22,000 TEU container ship (Asiasis, 2008). Technical aspects that are relevant in this phase are the following: propulsion, stability, container support, weight and strength (Wijnolst and Wergeland, 2009). The questions about propulsion are whether or not one engine and one propeller is enough to move the ship. The 'standard' sailing speed of large container ships is 25 knots. The question is whether for such large Malacca-max container ships one engine is enough to sail at that speed. The answer is simple, no. The 18,000 TEU container ships Maersk ordered are powered by two engines. Even larger ships will obviously also need two engines. The second technical aspect is stability. The containers need to stand stable when transported. The number of deck containers is mainly determined by the stability demands. If containers are not loaded stable, accidents can happen. Container support has similarities with stability. Since mega ships do not have hatch covers, measures have to be taken to prevent excessive stack loads. Container ships have a support system for the deck containers. The fourth technical aspect is the weight of the container ship. Several methods are available for estimating the steel weight of the ship. The method Westers, the method Sneekluth, the method Vossnack and the midship extrapolation method can be used. The fifth technical aspect is the strength of the mega ships. The container ships need to be strong enough to carry all the containers and withstand all the forces. The technical details will not be discussed further. Combining all these technical calculations leads to the conclusion that it is technically feasible to build Malacca-max container ships. There are still uncertainties however and a lot of further research is needed.

But are Malacca-max ships also economically viable? The costs of such a large container ship are really high. Capital costs, operational costs, voyage costs and the cargo handling costs will be higher in absolute terms. If only the absolute costs are considered, a mega ship would not be economically viable. But relative costs, so for example the costs per TEU will be lower (in amongst Wijnolst and Wergeland, 2009). This has to do with the achieved economies of scale, as discussed before. So theoretically spoken, Malacca-max container ships are also economically viable. Whether these ships are also in practice viable is uncertain. Earlier research shows both sides. Some research shows economies of scale can still be achieved, others show they do not. It depends in amongst from the variables. Last aspect that influences the decision is the environmental aspect. This includes both the circumstances for the ships to operate, and the environmental influence of the ships. Ships are dependant of the circumstances in which they operate. Two of the most important shipping channels in the world, the Suez Canal and the Strait of Malacca have their limitations. Ships cannot be wider than the width of the canal. Depth is another issue that should be considered. This environmental aspect limit the newly developed ships. Also the consequences of the ships for the environment need to be considered. Global warming and climate change are hot issues these days. New requirements should be included in the design of new ships. This is something that was less important in earlier phases. CO2 emissions are now more important and relevant than they were twenty years ago. Ship designers and shipbuilders need to consider the environmental effects of new container ships.

Phase I and II

Phase I and II will be combined since the aspects that were relevant have similarities with each other, and with phase III. Both in phase I, the period 1984-1995, with largest container ships growing till a capacity of 4,500 TEU and in phase II, the period 1995-2006, with largest container ship capacity growing from 4,500 TEU till 10,000 TEU technical - and economical aspects were most relevant. Environmental aspects were less important in these two phase. In general there was less concern about the environmental effects of all kinds of actions, whether this was driving a car or sailing with a container ship. The general view on the increasing ship size is that multiple links in the supply chain need to adjust. Multiple links need to make investments in for example deeper channels or quay cranes to handle the larger container ships (in amongst: Harrington, 2001). Whether container terminals and hinterland connections were able to handle all the containers was a point of concern. More investments were needed to provide a solid system to accommodate to larger container ships. There was quite some discussion about the question whether increasing ships would lead to a hub-and-spoke network instead of a multi-port calling network. Both situations were discussed. Fewer ports could handle the largest container ships, and therefore less ports would be served. In the end of the second phase and in the third phase there has been a movement towards a hub-and-spoke network, but the current market situation is not a pure hub-and-spoke network. Both networks can be found in the liner shipping market, and a combination of the two is also visible. Another economical consequence relating to both the fewer ports called and the increase in ship size is the cost of transhipment that would increase, according to Schinas and Papadimitriou (2001). Containers need to go through more nodal points than before and this will increase the cost of transhipment. Other technical- and economical aspects are more or less comparable to phase III. Of course there are differences but the general thoughts and expectations are comparable.

A common argument in all three phases is that in each phase the ship size achieved is often seen as the maximum viable. Research does in general quite agree, although there are always different results. Technically viable is mostly not the point of concern. Technological developments and innovations make larger ships technically possible. Of course there are concern about propulsion for example, but technological development makes larger container ships possible. Economically viable however is a larger point of concern. Stopford (2002) for example questions the achieved economies of scale. In all three phases there are critics who question whether the economies of scale outweigh the extra costs.

4. Conclusion and discussion

This paper started with a quote from the CEO of Daewoo, Nam Sang Tae, who claimed the ordering of ten 18,000 TEU container by Maersk was a momentous event for container shipping. The absolute size may be momentous, but the trend that container ships increase in size is definitely not new. Ever since the introduction of the first container ships both the average size and the maximum size increased over the years. The average container ship is nowadays about 4100 TEU. The trend for increasing container ships has mostly economic incentives. Carriers try to achieve economies of scale by increasing the ships. Lower costs per TEU means achieved economies of scale. There are some other incentives behind increasing ship size, but economies of scale are the underlying explanation. But this trend has of course consequences. The main question in this research is: "*What are the consequences of increasing container ships for the carrier market, port authorities and container terminals".* The consequences were divided in two part, the consequences for the carrier market and the consequences for ports. The consequences for the carrier market are divided into three major trends. Horizontal integration, vertical integration and the investment in bigger container ships are the three trends in this market. Horizontal integration means that companies in the same link in the supply chain integrate and become one. This can be done in an internal or an external way. Horizontal integration is done to become larger and more powerful companies or institutions. Horizontal integration is partly caused by the increasing container ships. For example, the initial investment becomes higher, and larger companies can afford such investments easier. The second trend was vertical integration. Vertical integration is two links in the supply chain becoming one. Several factors favouring vertical integration have been mentioned. The relation between vertical integration and increasing ships is that the links that do benefit from increasing ship size try to reduce the total supply chain disadvantages. By vertically integrating the links that do not benefit from the larger ships, the total supply chain becomes better off. The last part of the consequences for the carrier market was about other consequences, not related to horizontal - or vertical integration. The trend for bigger ships created sort of a vicious circle. By investing in bigger ships, in order to achieve economies of scale, freight rates declined, because of more supply. Lower profits leads back to a cost reduction and the investment in bigger ships. Mentioned already, the trend of increasing ships generates extra supply. In the carrier market, a constant balancing between overcapacity, and a corresponding decline in freight rates and return on investment, and the profitability of the carriers. Last consequence was the decline in frequency.

The consequences for ports were discussed next. These consequences were divided into the consequences for port authorities and the consequences for container terminals and its operators. Port authorities create the circumstances in which companies can operate. Port authorities need to build and maintain the port to make it as attractive as possible. Port authorities face problems with larger ships. Ports often have a lack of space, and expansion of the port might be necessary to handle even the largest container ships. Another problem port authorities have to deal with is the draft problem. Larger ships have a larger draft. However, container ships do not have a much larger draft when the ship becomes larger, compared to other types of cargo ships. Because of this larger draft, the carrier market moves more to a hub-and-spoke network. Multi port calling networks are also still present, but less. The container terminal faces the most problems because of increasing ships, compared to the rest of the supply chain. Container terminal operators need to make large investments in material, such as quay cranes and automated guided vehicles. More containers need to be handled, so more material is needed to move the containers in and from the container terminal. What is really important is the container terminal efficiency. If container terminal do not operate efficient, and more containers need to be handled, the problem of congestion appears. If containers cannot be handled as efficient as possible, it takes longer. Carriers prefer to stay in the port as short as possible, since the economies of scale are achieved at sea. The time factor is crucial in liner shipping service. The faster the containers are handled, the better. During the last decades, the container ships have increased. There were always opponents and proponents. Technical -, economical - and environmental aspects were considered. Technically spoken, mega ships were always seen as viable. Technological development made larger ships possible. Economically seen, there were some doubts about the achievement of economies of scale. But up to and including now, the carriers decided to invest in larger vessels. Environmental aspects were especially important in the last phase. More environmental awareness also influenced the container shipping industry.

4.1 Concluding remarks

This paper discussed the consequences of increasing container ships for the carrier market and for ports. However, not all aspects have been discussed. Hinterland transportation is slightly mentioned in the port section since it was not the focus of this paper. This could be investigated further. The trend for increasing ships is still very active and relevant today, as can be seen by the recent ordering of Maersk. Therefore further research can be done, to find out what the consequences will be, and the adjustments need to be, in order to handle the latest generation of such large container ships. Are ships larger than the Malacca-max standard possible? The future will tell.

Appendix

Figure A1: Supply Chain Container Shipping

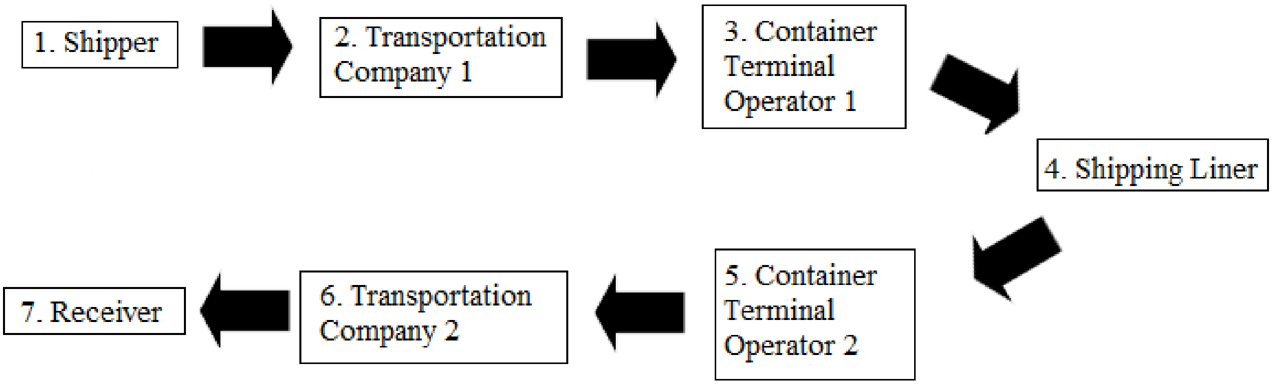
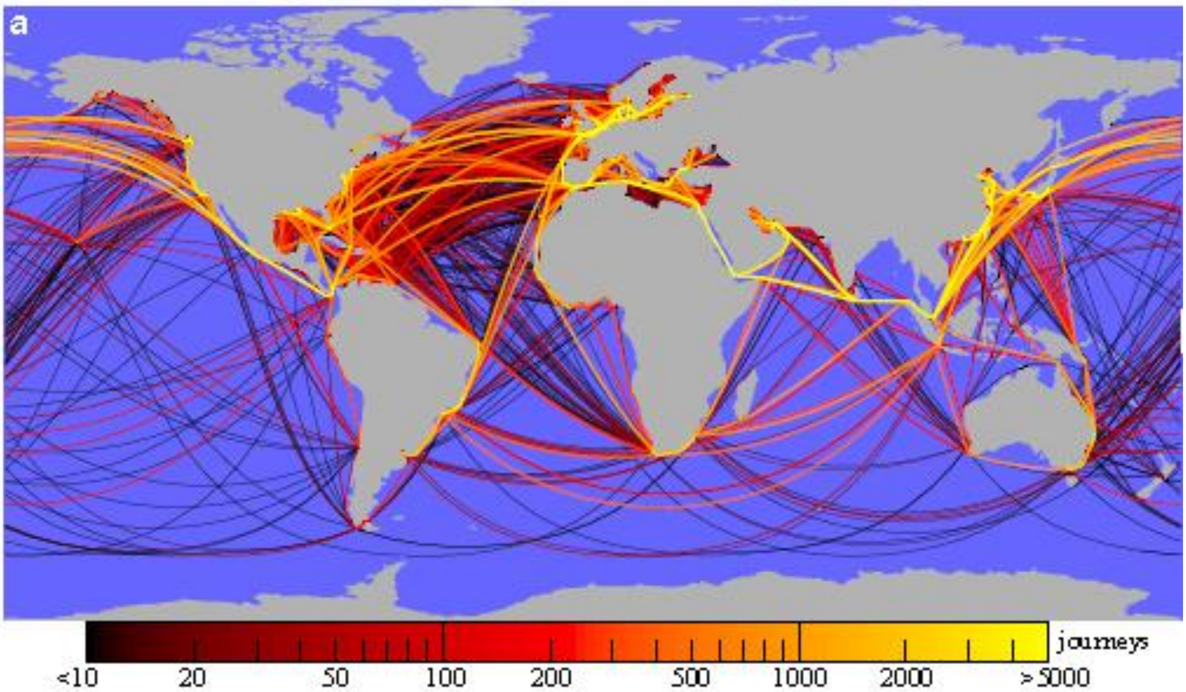


Figure A2: Number of journeys along each route



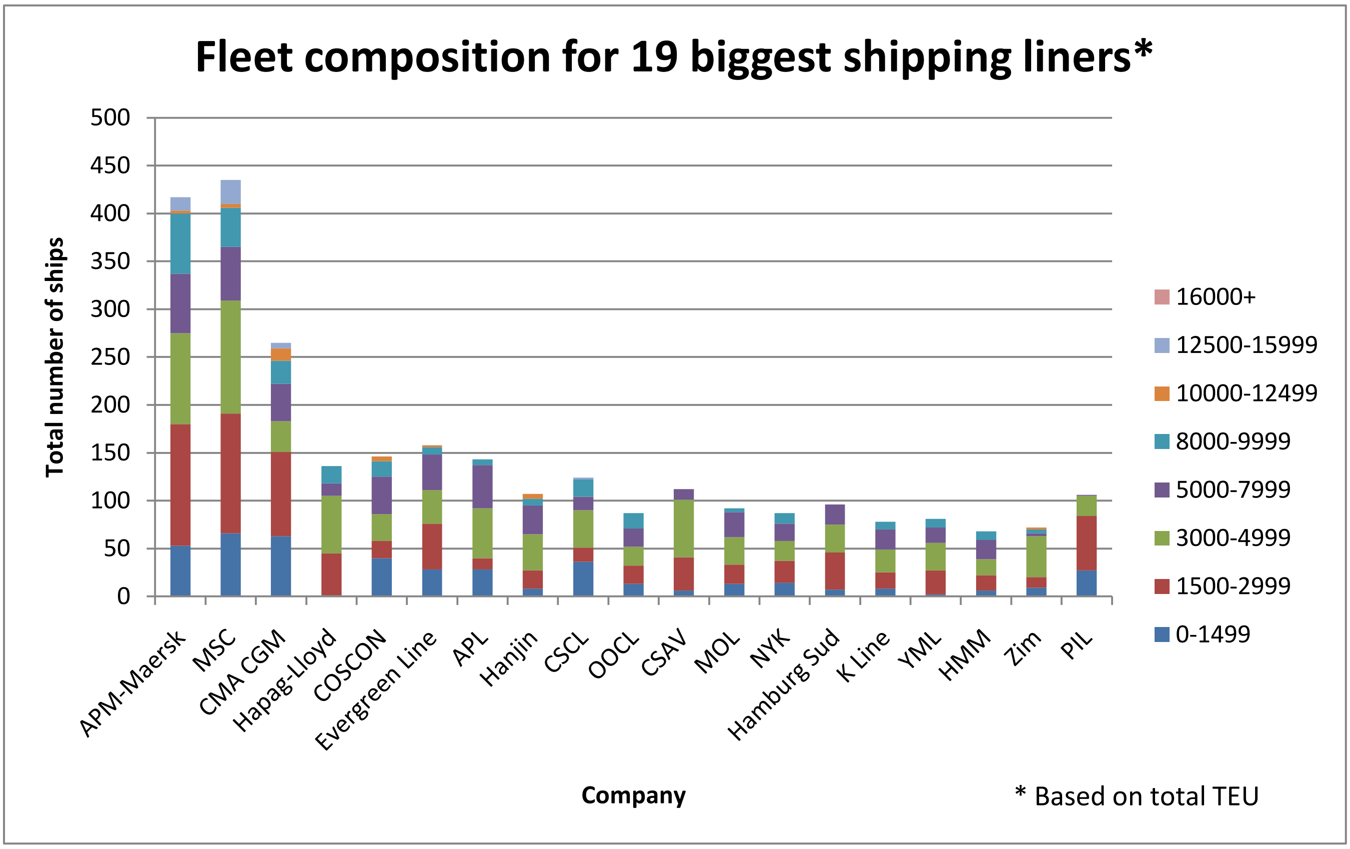
Source: Kaluza et al. (2010)

Table A1: Top 20: Operated fleets per 12 May 2011

Alphaliner - Top 20 : Operated fleets as per 12 May 2011												
		Total		Market share	Owned		Chartered			Orderbook		
Rnk	Operator	TEU	Ships	of total TEU	TEU	Ships	TEU	Ships	% Chart	TEU	Ships	% existing
1	APM-Maersk	2.287.445	604	14,9%	1.114.058	205	1.173.387	399	51.3%	416.042	52	18.2%
2	Mediterranean Shg Co	1.981.188	467	12,9%	1.003.464	211	977.724	256	49.4%	560.410	53	28.3%
3	CMA CGM Group	1.261.443	388	8,2%	484.023	93	777.420	295	61.6%	208.388	23	16.5%
4	Evergreen Line	612.911	165	4,0%	330.167	88	282.744	77	46.1%	176.000	20	28.7%
5	Hapag-Lloyd	590.780	135	3,9%	267.259	56	323.521	79	54.8%	131.000	10	22.2%
6	COSCO Container L.	589.762	142	3,8%	338.365	95	251.397	47	42.6%	296.536	36	50.3%
7	APL	587.983	146	3,8%	169.547	45	418.436	101	71.2%	204.480	22	34.8%
8	CSAV Group	559.722	144	3,7%	51.090	10	508.632	134	90.9%	98.589	12	17.6%
9	Hanjin Shipping	527.269	111	3,4%	239.492	40	287.777	71	54.6%	144.428	14	27.4%
10	CSCL	484.139	140	3,2%	287.716	74	196.423	66	40.6%	122.044	14	25.2%
11	MOL	411.866	97	2,7%	219.998	37	191.868	60	46.6%	50.445	9	12.2%
12	OOCL	409.352	88	2,7%	283.278	47	126.074	41	30.8%	193.216	17	47.2%
13	NYK Line	406.118	102	2,6%	309.403	59	96.715	43	23.8%	9.076	2	2.2%
14	Hamburg Süd Group	378.245	116	2,5%	175.326	43	202.919	73	53.6%	149.590	24	39.5%
15	Yang Ming Marine Trans	337.507	84	2,2%	193.789	46	143.718	38	42.6%	102.214	16	30.3%
16	K Line	335.817	79	2,2%	217.186	38	118.631	41	35.3%	58.672	8	17.5%
17	Zim	331.257	99	2,2%	165.674	36	165.583	63	50.0%	155.769	14	47.0%
18	Hyundai M.M.	307.323	61	2,0%	100.646	17	206.677	44	67.3%	65.460	5	21.3%
19	PIL (Pacific Int. Line)	256.903	136	1,7%	159.413	91	97.490	45	37.9%	67.806	22	26.4%
20	UASC	236.661	58	1,5%	126.696	28	109.965	30	46.5%	104.800	8	44.3%

Source: AXS Alphaliner (2011)

Figure A3: Fleet composition for 19 biggest shipping liners



Source: Authors' own elaboration based on data from Containerisation International (2011)

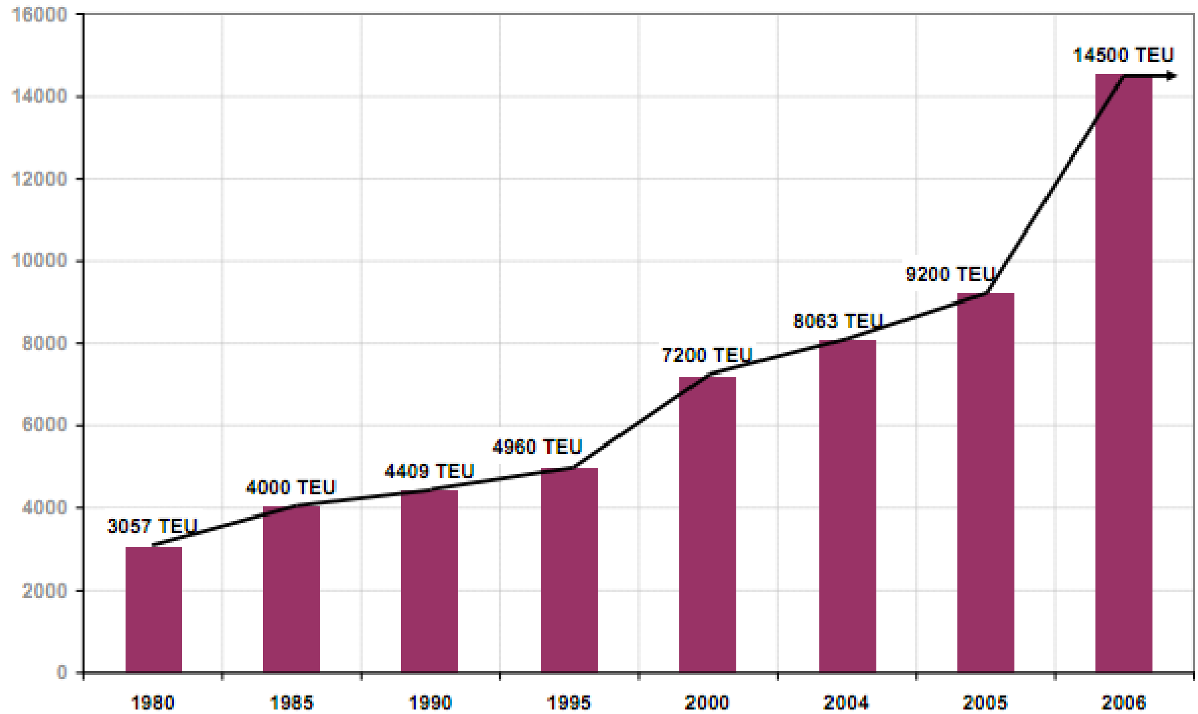
Table A2: Order book for containerships 2011-2015

	Total			2011			2012			2013			2014			2015		
Company	1*	2*	3*	1*	2*	3*	1*	2*	3*	1*	2*	3*	1*	2*	3*	1*	2*	3*
Maersk	416890	48	8685,21	131790	19	6936,32	86150	15	5743,33	72950	7	10421,43	54000	3	18000,00	72000	4	18000
MSC	388634	39	9964,97	133650	14	9546,43	209484	20	10474,20	45500	5	9100,00	0	0		0	0	
CMA CGM	234203	24	9758,46	142163	17	8362,53	92040	7	13148,57	0	0		0	0		0	0	
Hapag-Lloyd	134758	11	12250,73	15958	2	7979,00	66000	5	13200,00	52800	4	13200,00	0	0		0	0	
COSCON	296536	36	8237,11	90960	11	8269,09	165526	22	7523,91	40050	3	13350,00	0	0		0	0	
Evergreen Line	160000	20	8000,00	0	0		16000	2	8000,00	88000	11	8000,00	56000	7	8000,00	0	0	
APL	185400	20	9270,00	0	0		118200	12	9850,00	58800	7	8400,00	8400	1	8400,00	0	0	
Hanjin	147762	12	12313,50	29862	3	9954,00	78600	6	13100,00	39300	3	13100,00	0	0		0	0	
CSCL	113800	14	8128,57	21800	3	7266,67	92000	11	8363,64	0	0		0	0		0	0	
OOCL	141534	14	10109,57	2758	1	2758,00	17200	2	8600,00	103800	9	11533,33	17776	2	8888,00	0	0	
CSAV	6316	1	6316,00	6316	1	6316,00	0	0		0	0		0	0		0	0	
MOL	19020	3	6340,00	19020	3	6340,00	0	0		0	0		0	0		0	0	
NYK	36300	7	5185,71	18300	3	6100,00	18000	4	4500,00	0	0		0	0		0	0	
Hamburg Sud	175694	31	5667,55	21334	3	7111,33	54960	11	4996,36	89800	16	5612,50	9600	1	9600,00	0	0	
K Line	42412	9	4712,44	42412	9	4712,44	0	0		0	0		0	0		0	0	
YML	89900	14	6421,43	13200	2	6600,00	42300	6	7050,00	34400	6	5733,33	0	0		0	0	
HMM	1888	1	1888,00	1888	1	1888,00	0	0		0	0		0	0		0	0	
Zim	155418	14	11101,29	2450	1	2450,00	75312	6	12552,00	0	0		77656	7	11093,71	0	0	
PIL	34404	8	4300,50	7204	2	3602,00	21600	4	5400,00	5600	2	2800,00	0	0		0	0	
4*		326	8530,27301		95	7379,632		133	8671,9699		73	8643,8356		21	10639,619		4	18000

*1= Total Ordered ship capacity (in TEU)
*2= Number of ships ordered
*3= Average capacity of ordered ships (in TEU)
*4= Total number of ships ordered/Total weighted average ship capacity

Source: Authors' own elaboration based on data from Containerisation International (2011)

Figure A4: Evolution of the largest containerships



Source: Arduino and Carrillo Murillo (2010)

Figure A5: Shipping cost model

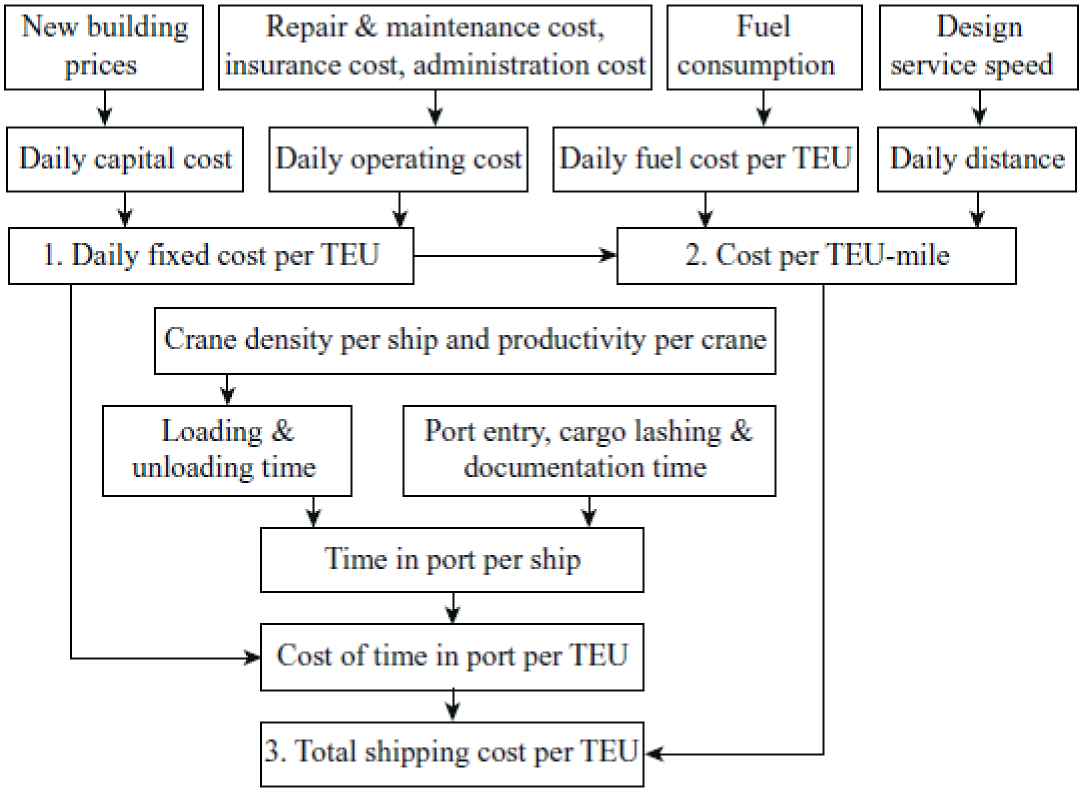
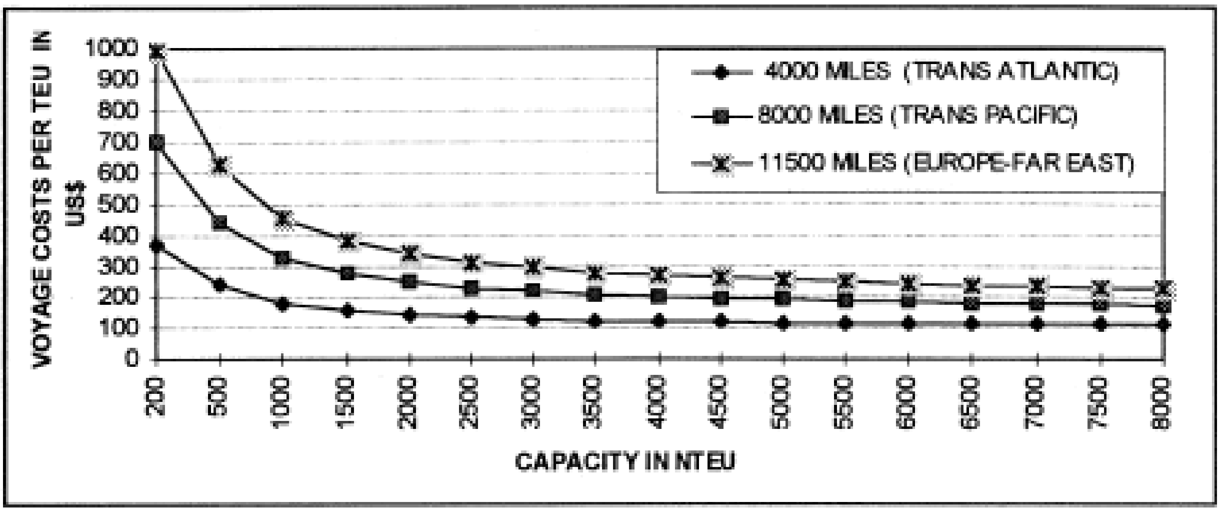


Fig. 1 Shipping cost model

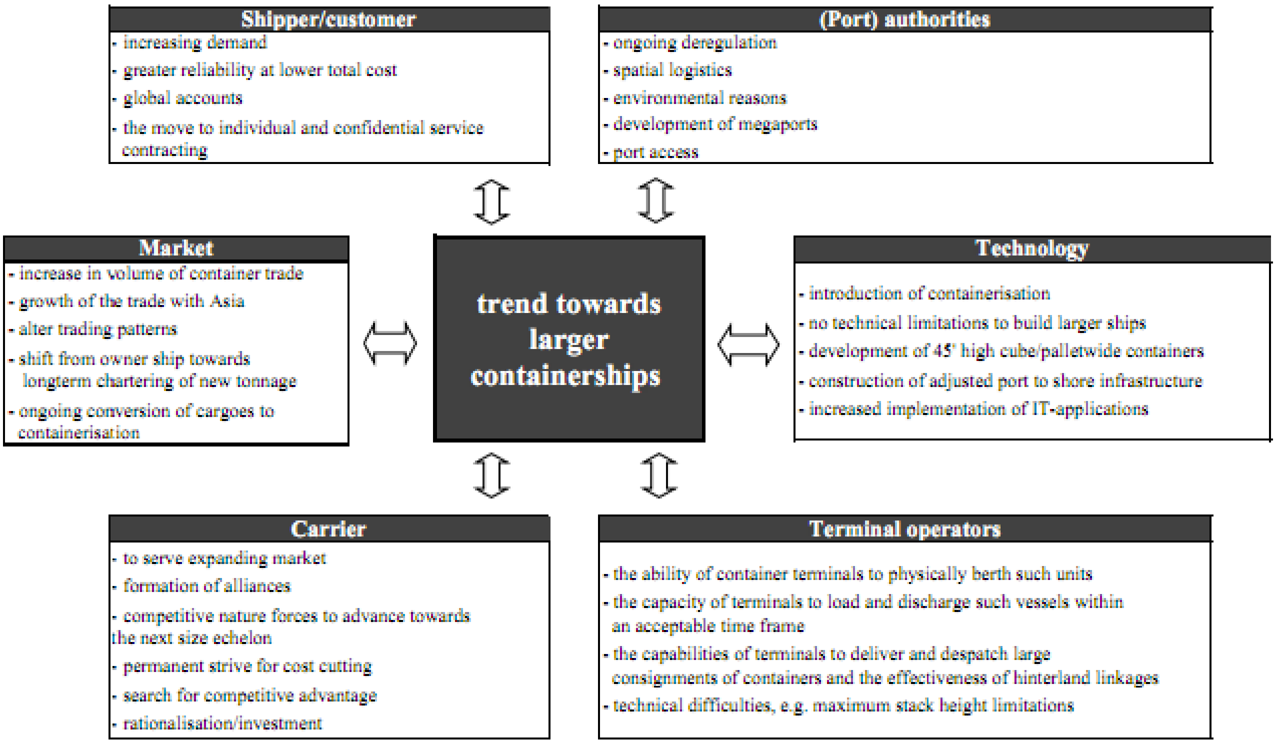
Source: Chen and Zhang (2008)

Figure A6: Distance comparison of total shipping costs



Source: Cullinane and Khanna (1999)

Figure A7: Influencing key factors of increasing ship size



Source: Sys et al. (2008)

Figure A8: Process of unloading and loading a ship

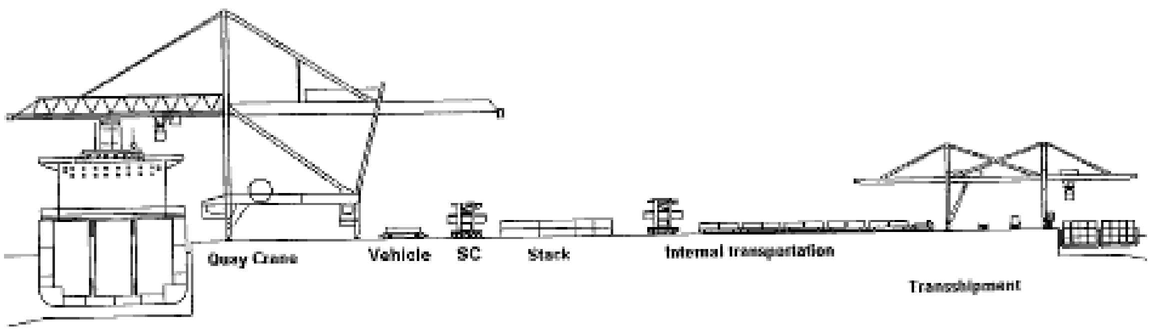


Fig. 1. Process of unloading and loading a ship.

Source: Vis and de Koster (2003)

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