Ocean container transport : an underestimated and critical link in global supply chain performance

Ocean Container Transport:

An Underestimated and Critical Link in Global Supply Chain Performance

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Abstract
With supply chains distributed across global markets, ocean container transport now is a critical element of any such supply chain. We identify key characteristics of ocean container transport from a supply chain perspective. We find that unlike continental (road) transport, service offerings tend to be consolidated in few service providers, and a strong focus exists on maximization of capital intensive resources. Based on the characteristics of the ocean container transport supply chain, we list a number of highly relevant and challenging research areas and associated questions.

1. **Introduction**

As supply chains become more global and more operations are being outsourced and moved offshore, the impact of transportation on supply chain performance is increasing. Nearly all intercontinental transport of goods takes place by sea, and an increasing share of this transport is containerized. Containerized ocean transport has become the lifeline of almost any global supply chain.

A wide variety of issues in transportation with an immediate effect on supply chain management have recently seen an increase in attention. These include tightened security (and hence increased vulnerability, potential delays, and requirements on information provisioning; see Willis and Ortiz 2004, for an overview of various security initiatives in the US, and Van Oosterhout *et al.* 2007, for a case study on the Port of Rotterdam; see also Sheffi 2001, and Lee and Whang 2005, for implications on supply chain management), increased congestion (and hence increased duration and variability of travel times; see European Commission 2001, for an overview of issues in the European Union across all modes of transportation), and heightened pressure on energy usage and carbon emissions (and hence different choices being made in modality or speed, see Dynamar 2007 and Kanter 2008). The security studies address nearly all stages of the supply chain including all modes of transportation with extensive emphasis on container transport. Congestion studies mainly focus on road transport, although airport congestion has also been studied specifically, albeit not specifically related to freight transport. While energy and carbon studies have been conducted extensively by economists, operational supply chain decision models taking emissions and energy into account are few, and again mainly focus on road transport.

Ocean container transport thus fulfills an essential role in today's global supply chains. Container transport has been heavily studied in the field of maritime economics. Containerization has been the main development in the maritime industry in the past thirty years, and its full effects are yet to be understood. Studies in the field of maritime economics typically either address strategic questions conceptually from the perspective of the port authority, terminal operator, or ocean liner company, or conduct empirical studies that describe certain aggregate trends or developments. In the operations research domain, a very particular stage of the container supply chain has been heavily studied, namely the operation of the container terminal (see Steenken *et al.* 2004, and Stahlbock and Voss 2008, for some recent reviews). These include for instance the scheduling of quay cranes, berths, and AGV carriers.

The impact of ocean container transport on supply chain performance and supply chain decision making remains significantly understudied compared to the impact of other aspects such as inventory management or road transport. However, typical supply chain management topics such as definition of contracts, management of variability, capacity management, and pricing policies are extremely important problems in ocean container transport with such specific characteristics that they warrant further study. In this paper, we will present a number of interesting supply chain management challenges that the ocean container transport industry is faced with, discuss those challenges from a supply chain management research perspective, and also explain the specificities of these challenges. Typically, they are different from the problems studied in maritime economics for a number of reasons. First, we are interested in operational decision making: for instance to develop decision procedures such that the supply chain can maintain a certain service level, or decide on a certain trading contract. Second, we are explicitly interested in the operational variability of this supply chain: to what extent does variability exist and how does this impact decision making (under uncertainty). Our paper will demonstrate that abundant opportunities for supply chain management research exist in ocean container transport with a major impact on the operations of the world's global supply chains.

The research issues we identified are based on an understanding of this industry that we developed over the past years in studying the literature, by extensively visiting a series of ports in Europe and Asia, by attending professional conferences that address the issues that the different parties in this supply chain are faced with, and by conducting a number of field projects to further increase our understanding of detailed processes. The paper hence has an extensive empirical basis but lacks a rigorous methodology due to the collected material from the visits being largely anecdotal. It however serves to initiate research in this field and help those not familiar with ocean container transport to acquire an understanding of the key issues from a supply chain management perspective. In this paper, we specifically focus on the decision and consequences of the *users* of the ocean transportation services, shippers and consignees, since they are most affected by the lack of attention in research on operational decision making in container supply chains.

We have designed the structure of the paper as follows. In the next section, we give an overview of the main characteristics of current ocean container supply chains. In section 3, we discuss some major trends that affect the operation of these supply chains. In Section 4, we present four new research themes that have emerged from our study. These research themes are in the supply chain management domain, and offer opportunities for both formal modeling research and empirical studies. We conclude in Section 5.

2. Today's global container supply chains

Since the shipping of "fifty-eight aluminum truck bodies aboard an aging tanker ship moored in Newark, New Jersey", which "five days later […] sailed into Houston, where fifty-eight trucks waited to take on the metal boxes and haul them to their destinations" (Levinson 2006), the world of container shipping has moved to a global trade which involves containers standardized at 20 and 40 feet, with fixed dimensions and properties, to be shipped all over the world. The road was not easy, but its eventual impact is enormous, with substantial reductions in shipping costs over decades. For an excellent study on the history of the shipping container we refer to Levinson (2006), who conducted a historical study and presents both anecdotal and statistical evidence on the impact of this technological revolution in logistics.

In the last decade, the global container trade has been growing excessively, primarily because of the offshoring of manufacturing operations to Asia, in particular China. Between 1989 and 2006, the international trade of China (sum of imports and exports) rose by 13.6% annually on average and 90% of the Chinese export value is transported by sea. In 2007, China's mainland ports (thus excluding those of Hong Kong and Taiwan) handled more than 100 million TEU (Twenty-foot equivalent container unit, the standard measure used in container trading) of products by sea. As reference, India's ports handled just over 7 million TEU in the same year (UNCTAD 2009). In 2006, more than 99% of United States' international cargo (by weight) was moved by sea cargo (Agarwal and Ergun 2008). Since the early 1990s, world container traffic has been growing at almost 3 times world GDP growth (UN-ESCAP 2005), while container port throughputs increased even faster due to an increase in the number of containers being transshipped. The worldwide containerized liner trade has risen from 11.4 million TEU in 1980 (Boile *et al*., 2005) to 137 million TEU in 2008 (UNCTAD, 2009), with an almost thirteen times increase. In 2008, world container throughput at ports amounted to 506 million TEU, an increase of 4% over the previous year, following multiple years of double-digit growth (UNCTAD 2009). These two numbers imply that on average, a container is handled about 3.7 times (up from 3.4 in 2007), inclusive of it being handled empty. Table 1 provides an overview of the largest containers ports.

Table 1: World busiest container ports: Source : UNCTAD, 2009 and Port of Rotterdam, 2007

Rank (2008)	**Port**	**2008** (kTEU)	**2007** (kTEU)	**2006** (kTEU)	**Rank (2002)**
1	Singapore (SG)	29,918	27,932	24,792	2
2	Shanghai (CN) *	27,980	26,150	21,710	4
3	Hong Kong (HK)*	24,248	23,881	23,539	1
4	Shenzhen (CN)	21,413	21,099	18,469	6
5	Busan (KR)	13,425	13,270	12,039	3
6	Dubai (AE)	11,827	10,653	8,923	-
7	Ningbo (CN)	11,226	9,360	7,068	-
8	Guangzhou (CN)	11,001	9,200	6,600	-
9	Rotterdam (NL)	10,800	10,791	9,655	7
10	Qingdao (CN)	10,320	9,462	7,702	-

** Includes river transport*

Table 1 shows strong growth in the Chinese ports, reflecting not only the actual growth in exports from China but also the fact that these ports take market share from regional hubs such as Kaohsiung. While the numbers indicate a strong growth trend, substantial caution should be taken in interpreting these numbers. There are several reasons for this. First, container traffic is generally measured as the number of containers handled in ports, rather than shipped end-to-end. This implies that in case of a direct shipment, the container is already counted twice: once at the port of export and once at the port of import. Since networks develop further towards a hub-and-spoke system that is similar to the global passenger airline industry, every individual container tends to be handled several times within a single container terminal, for instance when it is transshipped from a feeder vessel onto a large long-distance ocean liner vessel. This means the container is counted twice more in port statistics. For instance, the port of Singapore is primarily dependent on transshipments (UN-ESCAP, 2005), while for instance in Rotterdam this is 27% (Port of Rotterdam, 2007). Second, handling of empty containers is also included in port statistics. Furthermore, different definitions apply, since for instance the ports of Hong Kong and

Shanghai include river transport into their figures (implying that a single container coming from the hinterland by barge would also be double-counted), while the other ports do not. From the port of Rotterdam, for instance, more than 30% of the containers coming from or going to the hinterland are transferred by barge (Port of Rotterdam, 2007). These interpretations of statistics make it very hard to compare data from various sources and one should be careful in making too specific conclusions. However, the general conclusion that world trade is growing at more than double the growth pace of the world economy, that trade using containers is growing at about triple the pace of world GDP growth, and that container terminal throughput is growing at an even higher pace, appears to be a valid conclusion given the various studies that we have cited.

Table 2. Largest container liner companies in the world (in 1,000 TEU) in January 2006 and January 2002 (original data on which this analysis is based can be found in BRS, 2006 and Alphaliner, 2010), and their compound annual growth rate over the period 2000-2010.

February, 2010					**January, 2000**		
Rank	*Liner*	*kTEU*	*Share*	*CAGR*	*Rank*	*kTEU*	*Share*
1	A.P. Möller-Maersk (DK)	2050	14.9%	12.7%	1	620	12.0%
2	MSC (IT/CH)	1528	11.1%	21.1%	5	225	4.4%
3	CMA CGM Group (FR)	1050	7.6%	23.9%	12	123	2.4%
4	Evergreen Group (TW)	554	4.0%	5.7%	2	317	6.2%
5	APL (US)	544	4.0%	10.1%	6	208	4.0%
6	Hapag-Lloyd (DE)	491	3.6%	16.9%	14	103	2.0%
7	COSCO Container L. (CN)	454	3.3%	8.6%	1	620	12.0%
8	CSCL (CN)	438	3.2%	17.6%	18	86	1.7%
9	Hanjin (KR)	428	3.1%	5.8%	4	245	4.8%
10	NYK (JP)	407	3.0%	9.4%	5	225	4.4%

Table 2 contains an overview of the largest container liner companies in the world. Substantial consolidation has taken place in this industry over the past five years. Currently, the top-10 companies together have more than 50% market share. Consolidation thus moves much faster than in other logistics industries. For instance, in global contract logistics, only one company (DHL Exel) had a market share larger than 5% in 2006 (Datamonitor, 2006). This is likely due to the high capital intensity of the container liner industry. This difference in level of consolidation potentially explains the dominant market power of the ocean carriers in this supply chain (see also Section 4.2).

The overall container supply chain involves many different parties. A good overview of these is provided by Willis and Ortiz (2004). The shipper usually contracts a third party to take care of the container shipment. This could be a third or fourth party logistics service provider, which in this industry is often (but not necessarily exclusively) denoted as Non-Vessel Operating Common Carrier (NVOCC). They serve primarily as wholesalers of ocean vessel capacity, booking large blocks of container space with the ocean liner companies, and sell these out in smaller quantities to shippers. The NVOCC thus holds a contract with the shipper on the one hand and the ocean liner company on the other. Very large shippers would contract the ocean liner companies directly, without intervention of an NVOCC. A crucial step in each container supply chain is the terminal operator, who handles the container and moves it between different modes of transportation and between different ocean vessels in the hub-and-spoke system. Terminals are generally contracted by the ocean liner company and in some cases by the NVOCC. A challenge in this contractual relationship is that the terminal operator in its daily operations also deals with the hinterland transport operators (truck, rail or river barge), who deliver and pick up the containers but have no contractual relationship with the terminal operator. This implies that operational coordination of the container operations is a challenging task involving multiple decision makers. Some recent studies have addressed this problem using Multi-Agent Systems (see, e.g., Douma *et al.*, 2008). We refer to Section 4.2 for a further discussion on this topic and to Figure 1 for an overview of the contractual and operational relationships in this supply chain.

At the terminal itself, operations tend to be highly automated and/or mechanized, in order to ensure that vessels get loaded and discharged as quickly as possible. Consequently, investments in terminals are extremely high and tied up substantial amounts of (often government) capital. Due to the extensive capital cost, efficient operations of the terminals that maximize the throughput (terminals are paid by a handling charge per container) are essential for the terminal operators' profits. Terminals operations have been studied extensively in the field of Operations Research and many formal OR models are available and have been implemented. We refer to Vis and De Koster (2003), Steenken *et al.* (2004), Günther and Kim (2006), and Stahlbock and Voss (2008) for review papers of this extensive research area.

In every operational purchasing relationship, buyer and supplier agree on a split between them of the costs and risks of the transport of their goods. These trade agreements have been standardized by the International Chamber of Commerce. Depending on the specific trade agreement between buyer and supplier, relationship in the supply chain will be different. For instance, under a so-called *Ex Works (EXW)* trade agreement, the buyer is responsible for arranging the pick-up of the goods from the supplier's warehouse and arranging the entire transportation to its own incoming goods warehouse. On the other hand, in a popular trade agreement, called Free on Board (FOB), the point of title transferred occurs when the goods has passed over ship's rail. Namely, it is shipper's responsibility for transporting goods to a vessel, loading aboard and export clearance. Once the goods are loaded the risk of loss and costs of transport reverts to the buyer. We will discuss these trade agreements in further detail in Section 4, when we will discuss the distribution of risk and cost in the supply chain, as this potentially affects decision making behavior by each of the parties involved.

3. Main developments in the supply chain: insights from previous studies

The ocean container transport industry has been affected by a number of dominating trends over the past five years. We will briefly review the most important trends to get readers in the supply chain management field up to speed.

A very important development that drives a lot of decision making is the general move towards hub and spoke networks. Increasingly larger containers ships (now up to 14,000 TEU) are used to transport containers between large hubs such as Hong Kong, Shanghai, Shenzhen, and Rotterdam, while smaller feeder vessels are used to bring the containers to the hubs from smaller ports and again from the downstream hub to the port of destination. The main driver has been the cost per container, which is lower for larger vessels due to economies of scale in construction, manpower and energy usage. It is unclear to what extent these hub-and-spoke networks will further develop. Due to the large volumes, also the number of direct scheduled services between many different ports has been increasing. The general expectation (UN-ESCAP, 2005) is however that the share of total container transport that is transshipped in hub-and-spoke networks will increase slightly.

The entire industry is very much driven by economies of scale. Economies of scale can be obtained in ocean vessels due to fuel efficiencies. Alfred Marshall is quoted by Clark *et al.* (2004): "a ship's carrying power varies as the cube of her dimensions, while the resistance offered by the water increases only a little faster than the square of her dimensions". This drives the growth of container vessels and is the main driver behind the growth of the hub and spoke network. Obviously, further economies of scale exist in the building of the vessel and in its labor costs. Economies of scale also are present in container terminals, as investments for berths are substantial and concave in container throughput capacity (UN-ESCAP 2005).

Marine cargo is heavily affected by energy prices. To our knowledge, well-researched public sources are not available. It has been reported (Wellins 2008) that the price of bunker cost has grown significantly and has now exceeded 35% of total vessel cost. Though we need to take great care in using these figures, they do indicate a high share of energy costs. In our interviews (during 2007 and early 2008), energy cost shares of 30-50% have been reported. UNCTAD (2008) reports various estimates for the last quarter of 2007, depending on vessel size, between 40 and 63%.

Table 3 and Figure 1 show the energy consumption of large container vessels dependent upon speed.

Table 3. Fuel consumption, expressed in US dollars per day at sea at various speeds and for three different vessel sizes based on July 2006 bunker price levels (Germanischer Lloyd, cited in Dynamar 2007)

At knots	5,000 TEU	8,000 TEU	12,000 TEU
18	23,100	29,000	36,500
20	31,800	39,400	48,700
22	43,700	52,200	64,400
24	59,300	69,400	83,600
26	82,800	96,100	114,700

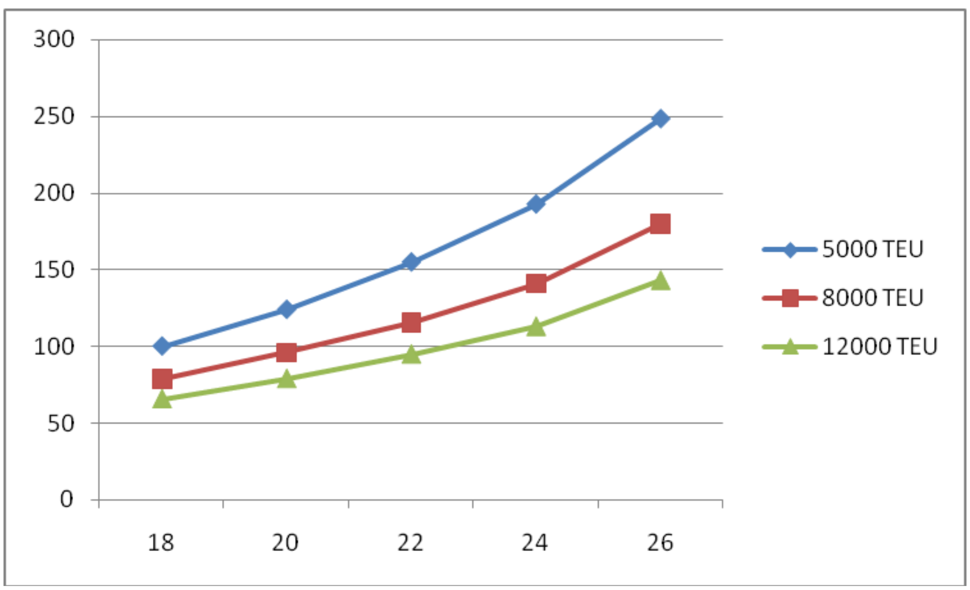

Figure 1. Fuel consumption cost per container per nautical mile, indexed (18 knots and 5,000 TEU vessel =100), based on figures in Table 3.

It is clear that further increases in energy prices will further affect this ratio. This will impact the choice of vessel size but also the cruising speed. For the supply chain, it will be quite impactful if speeds are reduced to save on fuel cost. A decrease in speed will not only affect the leadtimes of transportation, but also the overall capacity available for container transport, as fewer trips can be made within a certain timeframe.

The important trend of manufacturing outsourcing and offshoring has direct consequences on the type of merchandise shipped via ocean transports. While ocean transport traditionally transported predominantly raw materials and agricultural product, this later shifted to consumer products but is now dominated by intermediate products, i.e. products upon which additional value adding operations take place in the country of import (Feenstra, 1998). This suggests a further increasing importance from a supply chain perspective, as not only consumer products, but also intermediates are shipped via ocean container transport, thus indicating even more than a single ocean link in the supply chain. An interesting example is the manufacturing and recycling of laser printer cartridges. After the cartridges have been used, they are collected for recycling. The recycling process is labor intensive, and one of the companies that one of the authors worked with, shipped the empty cartridges from Europe to China, and then returns them to Europe for a second sale as a remanufactured product. Within their closed-loop supply chain, two ocean shipments were included.

A final important issue that is often discussed and is actually an important problem in this industry is the issue of container imbalance. With the load device being standardized, this container is also not disposable but is meant for multiple usages. However, the transport of full container loads is very unbalanced, since Asia (in particular China) exports much more than it imports; the reverse is true in most other areas of the world, in particular Europe and North America. According to statistics and forecasts (Dynamar, 2007), the trade imbalance in trans-Pacific liner trades is more than 10.6 million TEU in 2006, and expected to reach almost 11.9 million TEU in 2007 and 13.2 million TEU in 2008. For the Europe - Far East trade, the imbalance is about 6.5, 7.9 and 9.1 million TEU in 2006, 2007 and 2008, respectively. Furthermore, “60 percent of the containers that crossed the Pacific Ocean from Asia to North America and 41 percent of the containers on European routes came back to Asia empty in 2005” (*International Herald Tribune* 2006). Due to strong seasonal dynamics and imbalanced trade, Asia is always an area where empty containers are in demand, while the US and Europe are areas where empty containers are in surplus. Empty container movements reportedly cost more than USD 11 billion which accounted for 20 % of the total ocean container movement cost (*Journal of Commerce* 2004).

Extensive studies have been conducted regarding the empty equipment management problem. Quantitative analysis can be found in White (1972), Florez (1986), Dejax and Crainic (1987), Crainic *et al*. (1993a; 1993b), Lai *et al*. (1995), Shen and Khoong (1995), Du and Hall (1997), and Cheung and Chen (1998). Recently, Song (2006) used a Markov decision process approach to characterize the optimal empty container repositioning policy, Zhou and Lee (2007) use a mathematical model to study the pricing policy and outcome of competition between two firms regarding empty container reposition. Ding and Lee (2007) use chance constrained programming to solve an empty container reposition problem for transshipment routes. Qualitative and statistical industry oriented reports and articles represent an interesting source of reference and information (e.g., Behenna 2001, Boile *et al.* 2005; Boile 2006, Cargo Systems 1999, Crinks 2000, Drewry Shipping Consultants 2003, Dyna Liners 2007, LeDam, 2003, and The Tioga Group 2002). While this kind of literature helps greatly to gain a broad understanding concerning empty container management, the quantitative models are still far from applicable for solving realistic large scale problems, and do not address the inherent issue of trade imbalance.

4. Container shipments from a supply chain perspective: new issues

The issues mentioned above are interesting and have been widely studied and reported on. Moreover, in those areas still substantial research questions remain to be answered. The objective of this paper is, however, to present and discuss a number of problems and related research questions that have have been understudied in the literature (academic and industry), and yet appear to be challenging for the industry of container shipping. In this Section, we will outline four of those industry problem areas, namely:

- The coordination of container shipments across the container supply chain
- Pricing and risk management in the container supply chain
- Competition between ports, carriers and container terminals
- Capacity management in the container supply chain

Based on our analysis of the industry, we believe these four areas represent challenging problems in this industry, are related to very interesting research questions, and provide extensive opportunities for researchers in the field of operations management to contribute. The impact of such research will be substantial due to the enormous impact of ocean container transport on most of today's supply chains. Together, they therefore constitute a research agenda for supply chain management research in ocean container transport. The common characteristic of these research topics is that they affect the performance of the entire supply chain rather than addressing specific issues of the various entities that provide logistic services. Moreover, we have selected these specific topics because supply chain management researchers can contribute towards a better understanding and towards the development of decision support models. We will discuss each of these four topics in detail in this Section.

4.1 Coordination across the container supply chain

Willis and Ortiz (2004) provide an extensive description of the different parties involved in getting a container shipped from the vendor's location to the buyer's location if ocean container transport is involved. Above, we have outlined that various parties are involved in this transport apart from the buyer and the supplier, such as a logistics service provider, an NVOCC, an ocean carrier, one or more terminals operators, and one of more hinterland transport operators. This is then only related to those parties having in one way or another a contractual relationship, and does not include other parties such as customs and regulatory bodies, and banks that arrange the financial transaction depending on the trade agreement and the actual position of the container in the supply chain. In this supply chain, there is generally not a party who really controls the end-to-end transport of the container. While this argument can be put forward for any supply chain, the fact that the load carrier (the container) and the transportation service provider have been decoupled substantially adds to the complexity. While this decoupling is the primary drive for productivity increase (container cargo reduces handling costs as compared to break bulk cargo), this also causes coordination problems that are inherently more complex than in traditional supply chains. Moreover, the containers are also effectively used as warehousing capacity, which further increases the complexity of interactions. NVOCCs and logistics service providers try to get into a position where they can exert sufficient influence to be the *de facto* director of transport in this supply chain.

However, the high capital intensiveness of both the ocean liner industry and the terminal operators lead to generally poorly controlled systems with extensive queuing characteristics under complicated priority settings at each of the stages that the container needs to pass. Transit time has become more and more important, and has become one of the dominating factors in selecting the ocean liner company (Notteboom 2006). From a supply chain management perspective, the transit time is the most important variable determining the lead time in supply chain models. Roughly speaking, transit time consists of hinterland transportation (on the sending and receiving end), terminal dwell time (on both ends and on the transshipments points) and sailing time. In the sailing time, there are two types of reliability: schedule reliability and transit reliability (Notteboom 2006). A schedule is a published timing of a round-voyage of a specific ship. Liner companies may adjust schedules to increase transit time reliability while affecting schedule reliability. Notteboom (2006) mentions an example where a carrier reroutes ships to avoid congested ports, and then using inland transport to transport the cargo to the required destination to maintain transit time reliability. Obviously, substantial cost may be involved for the carrier. He mentions that – based on a survey among shipping lines - by far the most important cause for schedule unreliability is port and terminal congestion.Vernimmen *et al.* (2007) argue that schedule reliability is also heavily affected by the position that the port takes in the sequence of ports that the vessel calls. Schedule reliability is likely to be higher in those ports that are first port of call (for import cargo). On the other hand, schedule reliability in a port that is only fifth or sixth port of call in a certain loop is heavily dependent on time delays experienced in the previous four or five ports.

Saldanha *et al.* (2006) analyze the sailing time performance of ocean container carriers based on data from a large shipping movements database. The main purpose of their study is to show that substantial differences exist in sailing time performance between different carriers; and in fact substantially larger than is generally subsumed. From a supply chain perspective it is interesting that they have also explicitly measured the standard deviations of the sailing time, in addition to determining the averages. Their data suggest that in the estimated sailing time a standard deviation of up to 3 days exists, depending on the carrier and the route. Leachman (2008) in a study on California ports concludes that from a supply chain perspective reliability is important, but may not justify substantial additional costs. His study is one of the few in which he analyzes the costs of infrastructure and service providers and compares them to the costs that the shippers and consignees make in terms of keeping extra safety stock.

To our knowledge, Leachman's work is the single published study that models operational containers flows (including stochastic behavior) and taking the perspective of the container. In the maritime economics literature models exist that also take the container perspective , but fails to take the operational coordinaton problems into account (see, e.g., Luo and Grigalunas 2003). The transit time of the container is relevant for the user of container transportation services, and as Notteboom (2006) indicates, it has developed to be one of the primary reasons for selecting a carrier. It is therefore even more remarkable that so little empirical and modeling research exists taking this perspective.

Empirical research could entail both qualitative and quantitative studies. While our understanding of the contractual relationships in the supply chain is based on a small and selective sample (see our discussion of contracts for some examples), there is a need for more systematic work. Some preliminary work has been conducted in this field by Lee and Wong (2007), who conducted a survey to better understand the actual decision makers deciding on the choice of ports in the Pearl River Delta. A second interesting subject for empirical research is the duration of actual container transport and gaining understanding of variability in container lead times. Ratliff *et al.* (2006) announce a large scale project in which they attempt to get access to data that enables them to build a database of transportation leadtimes, with specific attention on lead time variability. Their idea is that because of transshipments and delays at terminals, actual transit time delays from the container perspective are substantially larger than the relatively low standard deviation that the study of Saldanha *et al.* (2006) suggests, Both of these examples illustrate the different type of empirical questions that SCM researchers would be interested in, as compared the maritime economists who have conducted extensive empirical research in this domain for decades.

Modeling research would address the traditional coordination and planning questions. The eventual research question to address would be how to coordinate a supply chain where both the carrier (ocean liner) and the handling agent (container terminal) are capacity constrained, which leads to substantial variability in leadtimes. Partial research questions are many, including contracting relationships between the various parties, operational coordination with stochastic leadtimes, operational coordination with lane, carrier, or terminal choice, etc. These research questions are strongly related to the topics we address in Section 4.2 and 4.4. This research obviously has strong links to the inventory management literature, including literature on visibility, contracting, multi-echelon inventory theory with stochastic leadtimes (see, De Kok and Graves 2003, for a recent overview of the state of the art in these fields). The inventory management literature however generally abstracts from the dominant problems in this industry, such as stochasticity in transportation lead times, delays in handling at terminals, and the absence of a contractual relationship between some parties. Some recent research (see, e.g., Douma *et al.*, 2008) models some of these coordination problems as a multi-agent system.

Research addressing these coordination problems would specifically need to address the fact that multiple players in this supply chain are primarily focused on optimizing the utilization of their expensive resources. For instance, both ocean carriers and terminal operator are aiming at very high utilization of their investment, which – under stochastic demand – may lead to substantial variance in performance.

This supply chain is an excellent example of a supply chain in which contractual and operational relationships are not aligned. Let us take the example of the logistics service provider, ocean carrier, terminal operator and hinterland carrier (see Figure 1). The operational coordination between the terminal operator and the hinterland carrier is important for the overall performance of this supply chain, and will affect the lead time reliability of a container that the logistics service provider can offer to its customers. Is is possible to design the contracts between LSP en ocean carrier, and those between LSP and hinterland carrier such that this coordination is optimal?

4.2 Pricing and risk management along the container supply chain

All contracts that are operational in this supply chain contain provisions on price setting and risk sharing. Carriers are paid a transport charge dependent on the specific route that they operate. Carriers then typically have the freedom to choose the detailed execution of the route, such as choosing whether to operate this on a direct liner or via the hub and spoke network (see Agarwal and Ergun 2007, for an interesting algorithm that combines scheduling and network design for container cargo). This latter choice obviously affects the overall transportation lead time from the container perspective. Based on our observations across several continents, and discussions with various parties in the industry, we are led to conclude that the transportation lead time from the container perspective is typically not a part of the contract, or –alternatively but with the same impact – penalties for late delivery do not exist or are not executed in the contract between the shipper and the ocean liner. It is not clear from the literature nor from our limited empirical work why this is the case. A potential explanation is that due to the fragmentation along the supply chain, there is no party willing to accept such responsibility. The results by Notteboom (2006) about the causes of delays also suggest that delays are closely intertwined: a delay by an ocean vessel may lead to a different allocation of berth places on the quay, which again may lead to delays at other ocean vessels having to reroute. It then becomes not very easy to assign the cause of a particular delay to one of the parties in the supply chain. The transport prices furthermore typically hold provisions for changes due to fuel prices. Apart from the contracted prices, there are also published prices for many routes, but some argue that these prices are hardly ever paid due to most prices being negotiated in specific contracts (Levinson, 2006). Published prices are updated regularly and depend mainly on the fuel prices

Contracts regarding timing are much more stringent between the ocean liners and the terminal operators. Ocean liners usually have a contract with terminal operators in which they agree on a terminal charge per container handled. Note that a handling movement in the contract usually involves a single move, i.e. from a vessel to the quay or vice-versa. Furthermore, an operational contract is designed if an ocean liner books a slot at the quay for a specific time. Vessels announce their expected time of arrival about a week ahead of time, and provide the terminal with daily updates regarding their expected arrival time at the quay. From about 24 hours before arrival, the predictions tend to be accurate. Penalties exist both ways, both for the ocean liner not showing up (due to diverting its route) and delaying its arrival, and for the terminal if the quay is not available or the loading or unloading takes too long; however, these penalties are generally not executed to maintain the relationship between the terminal operator and the powerful ocean carriers. If an ocean carrier decides to change its route, and use a rival terminal or port, the ocean carrier is generally responsible for arranging the land transport to ensure that the container ends up at the terminal for which it was originally intended.

The main contract between the buyer and the supplier is standardized according to the so-called Incoterms™ (ICC, 2000). Incoterms™ specify the division of cost and risk between the buyer and the supplier. They specify when the product changes ownership and who is responsible for arranging and paying the transportation. Especially due to the long lead times in ocean container transport, negotiation of the right Incoterms™ is very important for a company’s cash flow position, as well as for its risk position. Consequently, dependent on the Incoterms™ agreed, the seller and buyer may display certain strategic behavior. To our knowledge, there is no academic work, neither theoretical nor empirical) on decision making related to Incoterms™, while these are actually very dominant in international trade.

The general contracting relationships are represented in Figure 1.

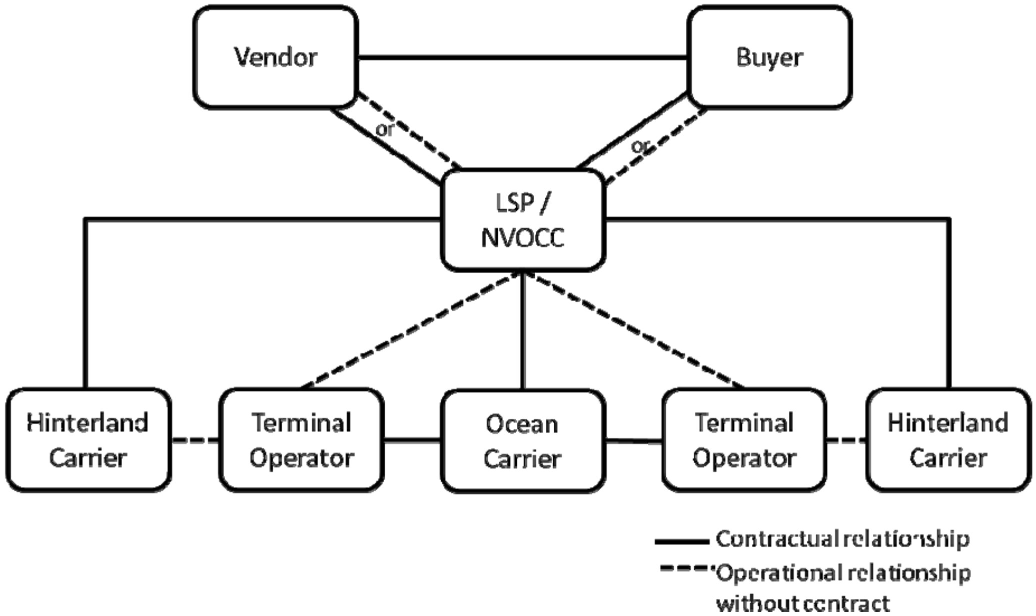

Figure 1. Contractual relationships and Operational relationships without contract in the ocean container supply chain.

The contracting literature (Cachon, 2003) does not appear to have researched any of the problems discussed here. Most of the literature involves contracts with an inventory risk, while this is not the case here. In case of capacity contracts, the literature involves contracts in which one party buy capacity from a supplier. There is some literature studying the shipping contracts between shipper and transportation companies. Kavussanos and Alizadeh-M (2001) investigate the nature of seasonality in dry bulk freight rates for contracts and compare it across freights of different vessel sizes. They found that while deterministic seasonal movements show similarities across vessel size and duration of contract, there are conspicuous differences too. Koekebakker *et al.* (2007) study the freight derivatives market. They propose a formula and show that their formula gives very accurate prices, in particular of forward-starting freight options. Garrido (2007) studies an electronic bidding system for the shippers to contract each shipment to a single carrier through an open auction and selects the carrier based on the best bidding price. Since the carrier will usually need to reposition the empty containers, they thus try to offer substantially lower shipping prices to the shippers to *generate* demand for these empty trips. The newly generated demand thus transforms shippers into bidders for the available capacity at discounted price. The paper shows that under a certain policy a spot price can trigger a demand generation for transportation services in the shippers' pool. Lim et al. (2008) study a shipper's transportation procurement model that involves an auction process, in which the transportation companies bid for routes to procure freight services from the companies, which minimizes its total transportation costs. The shipper gives assurances that shipments made in non-peak periods will be commensurate with shipments in peak periods. They formulate the model as an integer programming problem and develop a solution approach to solve it and also demonstrate the practical usefulness of the model.

The Incoterms™ clearly separate define the liability across international trade, the ownership of goods across international trade, and the responsibility for transport. Associated with ownership is cost associated with inventory holding such as cost of capital and obsolescence risk. Associated with liability is the risk of disruption occurring along the supply chain that may harm or loose the product. Associated with responsibility is the hiring of carriers, and negotiating rates (probably strongly related to buying power and volume). It is not very clear how these costs and risks interact, especially under assumption of strategic behavior by others in the supply chain. Under which conditions are which terms most favorable? And how does this impact the pricing?

4.3 Competition between ports, carriers and terminals in the container supply chain

Competition in this industry is fierce and is present in many parts of the supply chain. First, ports compete to attract terminal operators and obtain a place into the schedule of the ocean liners. In the Pearl River Delta in Southern China, the ports of Hong Kong, Shenzhen, and Guangzhou compete to attract containers for the Guangdong hinterland; in the Yangtze River Delta, Shanghai and Ningbo compete for business out of the vast Yangtze hinterland; in Northwest Europe, the ports of Le Havre, Antwerp, Rotterdam, and Hamburg compete to serve the majority of the European industrial heartland along Rhine, Scheldt and Elbe. Ports compete by investing in new quays, by ensuring good access from sea, or by moving new quays closer to sea. Furthermore, port authorities (who are mostly public bodies or publicly held companies) and national governments try to improve the strategic advantages of ports by improving the hinterland infrastructure, to ensure that shipments can reach the port and the hinterland without delay, and by ensuring deep-sea access (see, e.g., Robinson 1998, Cullinane *et al.* 2004, and Cullinane *et al.* 2005, for various qualitative case studies; Malchow and Kanafani 2001, Veldman and Bückmann 2003, and Nir *et al.* 2003 for econometric studies based on multinomial logit models; note that similar models have been developed and applied in the competition between airports, e.g., Pels *et al.* 2001). Competition between ports is generally seen as a field of public policy, but taking a supply chain view on these matters may seriously affect the port's strategy. Many ports deliberate whether they should maintain their traditional role of landlord and infrastructure provider, to allow terminal operators to conduct their business as good as possible, or to take more of a supply chain perspective and hence deliberately and proactively analyze goods flows developments and adapt an infrastructure with partners in the hinterland and at other ports that could better serve the container supply chain as a whole (Robinson 2002, Notteboom 2004). From a modeling perspective, these questions appear related to competition analysis in serial supply chains and questions of vertical integration (Corbett and Karmarkar, 2001), but a wide open area remains for studying port competition strategies.

To a certain extent, and definitely when it concerns more long-term strategic choices, the competition between terminal operators is similar to the competition between ports. However, in the shorter term competition between terminals holds different characteristics. Terminals compete for business from ocean carriers. They want ocean carriers to have their cargo discharged at their terminal. Availability of the quay is important, as ocean liners may decide to reroute ships to other terminals (within the same port or at other nearby ports) if the quay is not available and waiting time would be too long. This problem is similar to the one studied by Hall and Porteus (2000), who model shifting behavior of customers between service providers based on service achieved; service is related to capacity in previous periods. Terminals need to anticipate future arrivals of vessels, assess the number of containers that would need to be loaded and discharged and decide on actual requests of vessel operators to load and discharge containers. They are thus faced with an online order acceptance and scheduling problem. In the OR literature, the berth allocation problem has been studied extensively (Steenken *et al.* 2004), but these papers study this problem with a given set of vessels to be processed, and without considering strategic behavior of either the vessel operator or the terminal operator. For river transport, it is known that barge captains display strongly strategic behavior (Douma *et al.*, 2008). Our findings suggest that in order to allow for flexibility, ocean liners are restrictive on sharing information. Information regarding the number of containers to be loaded and discharged is often revealed at a late stage, leading to poorly controlled stacks of containers on the quay. Despite substantial increases in throughput, one of the terminals in a major European port reported to us that the average dwelling time of a container on the quay is still increasing. Apart from poor visibility on vessel plans, we also discuss an alternative explanation of this phenomenon in Section 4.4.

It is the general impression in the industry, based on our interviews, that the ocean liners are the most powerful party in this supply chain. Also in the literature (Robinson 1998, 2002), this is suggested. Clear theoretical explanations for this dominance, apart from the strong consolidation that has taken place in this industry, are not available and hence strategies how to deal with this dominance by the other parties in the supply chain have not been developed. This is a very interesting area of research. A potential explanation for the dominance of the ocean liners is that over the past years, they have formed alliances that effectively operate more or less closed networks. These alliances have some similarity to the alliances in the airlines industry, and the concept of “codesharing” in the airline industry. Agarwal (2007) is a very recent work and the first one that addresses the problem of alliance formation in container liner shipping using formal modeling.

4.4 Capacity management in the container supply chain

Due to the high capital intensity in this supply chain, the management of this capacity is a dominant trait. The capacity-orientation in container terminals explain to a large extent the extensive amount of operations research work that has been conducted to optimize terminals operations. This is not limited to theoretical work, as many OR applications are used in these terminals. In this section, we would like to address the management of capacity from a supply chain perspective, both from a tactical level and a more operational level.

At the tactical level, decisions need to be made upon investments in capacity. Investments in ports and terminals can largely be based on some of the competitive econometric models that we have discussed in the previous section, some of which aim to predict demand for container traffic at certain ports or terminals in a region. An example is the work by Veldman and Bückmann (2003) who, using a competitive model, predict the demand for terminal handling capacity in the port of Rotterdam to support investments leading to new quays. Competing ports will however make similar analyses and decisions on port expansions. This has some similarities to investment decision in highly capital intensive industries, such as the semiconductor industry and the machine tool industry. In these industries, is has been demonstrated that a significant bullwhip effect occurs as a consequence of cyclic investment patterns (Andersen and Fine 1998). The enormous and continuous growth in container transport in the past decade and the relatively slow expansion procedures in Europe may have dampened the bullwhip effect, as capacity utilization at terminals is still high. However, it is unclear what will happen when growth will slow down.

At the operational level, decision making is more complicated due to the high levels of capacity utilization in container vessels and terminals, as well as in some of the hinterland connections. Increased utilization leads to increased variability, and strategies for decision making are only few. The decisions are actually complicated by the fact that not all parties have a contractual relationship, as discussed above. Variability in lead times is high. According to Drewry (reported in Dynamar, 2007), "the share of ships arriving on the advertised date " was "Transpacific 63%, Europe-Far East 49%", and "Transatlantic 46%". We hypothesize that the increased dwell times that have been reported to us in European and North American ports are related to the high levels of capacity utilization both on vessels and in terminals. Taking a system dynamics perspective, increased utilization leads to increased leadtimes (due to waiting at the port of export) with increased variability, which causes the shippers to have their products sent early. However, they will not pick up their orders earlier than needed and leave them on the quay. Increased storage of containers on the quay reduces the efficiency of the handling operations on the quay and could effectively cause further capacity problems, this time at the quay. This line of thinking has been summarized in Figure 3.

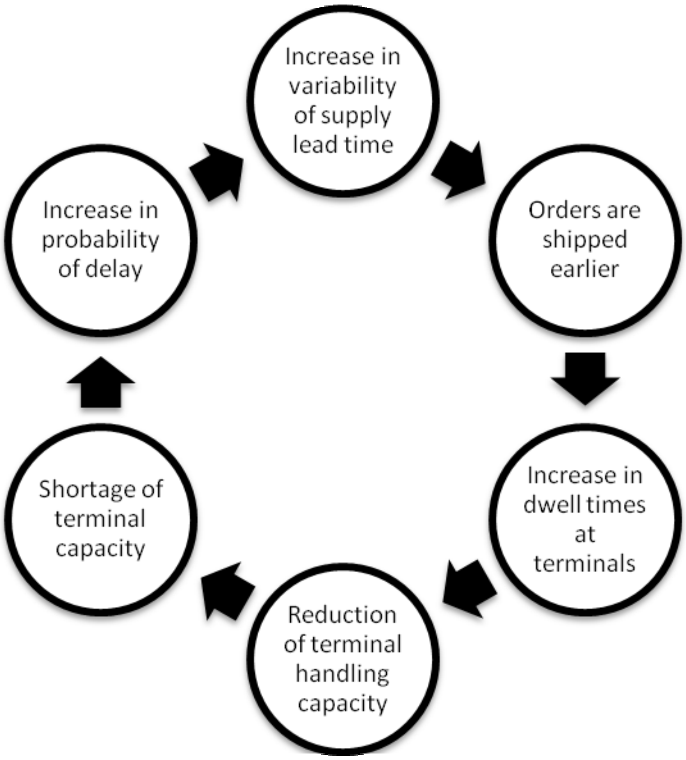

Figure 3. Relationship between delays and capacity usage.

This problem has similarities to production control problems in highly utilized systems and consequently variable lead times, relating to issues such as the leadtime syndrome (Mather and Plossl 1978, Selcuk *et al.* 2009). In the production control literature, various approaches have been developed to manage production departments with variable lead times (see, e.g., Pahl *et al.* 2005, and Missbauer 2006 for recent overviews of this work), and this could be a potential theoretical basis for addressing the problems in this industry characterized by high levels of utilization.

An alternative theoretical basis to relate these dynamics to is the bullwhip effect (Forrester 1958, Lee *et al.* 1997), to which a whole series of modeling papers is related addressing the countering of this effect, covering issues such as information sharing (value of information), and the countering of shortage gaming behavior (by contracting (see also Section 4.2). The focus of these papers is very much on the management of inventory. The reasoning above implies that capacity issues may be more dominant that inventory issues in this supply chain, albeit the variability in leadtimes does have immediate consequences on inventory policies and related inventory holding cost.

Strategies need to be developed for the various players in this supply chain, addressing questions such as:

- What are optimal ordering policies for shippers (especially *when* to place the order in order to obtain a reliable delivery)?
- What is the value of sharing information?
- How should penalties be set within contracts to provide for good incentives, bearing in mind that only some relationships are governed by contractual relationships?
- What should prices be for containers dwelling on the quay, bearing in mind to too high prices would turn shippers and liners away to competing terminals, but too low prices would transfer the quay into cheap warehouse space?
- What are good policies in establishing the coordination between non-contracted parties, for instance between the terminals and the hinterland carrier, for instance thinking of sequencing rules for the hinterland carriers to bring the container to or collect them from the quay?

Operations management studies addressing these and similar questions are few and far between.

5. Conclusions, managerial insights, and research agenda

In this paper, we have outlined the key characteristics of ocean container shipping, an essential part of today's global supply chains, and the primary link between manufacturing sources in developing economies and the markets in the developed world. We have noted that the supply chain impact of this mode of transport is significantly understudied, and we have identified four areas of research that can contribute to a better understanding and improved performance of the worldwide container supply chains. The four identified research areas are:

- The coordination of container shipments across the container supply chain
- Pricing and risk management in the container supply chain
- Competition between ports, carriers and container terminals
- Capacity management in the container supply chain

While discussing this segment of transportation and the related industries, we have demonstrated that it is heavily capacity oriented, with a particular dominance of the ocean liner companies that operate the still scarce capacity of vessels. While vessel capacity has been increasing and it will be only a matter of years until the overall capacity will have exceeded the worldwide demand for ocean transportation capacity, the substantial consolidation in this industry may serve to consolidate the relative power of the ocean liner operators in this supply chain as outlined above.

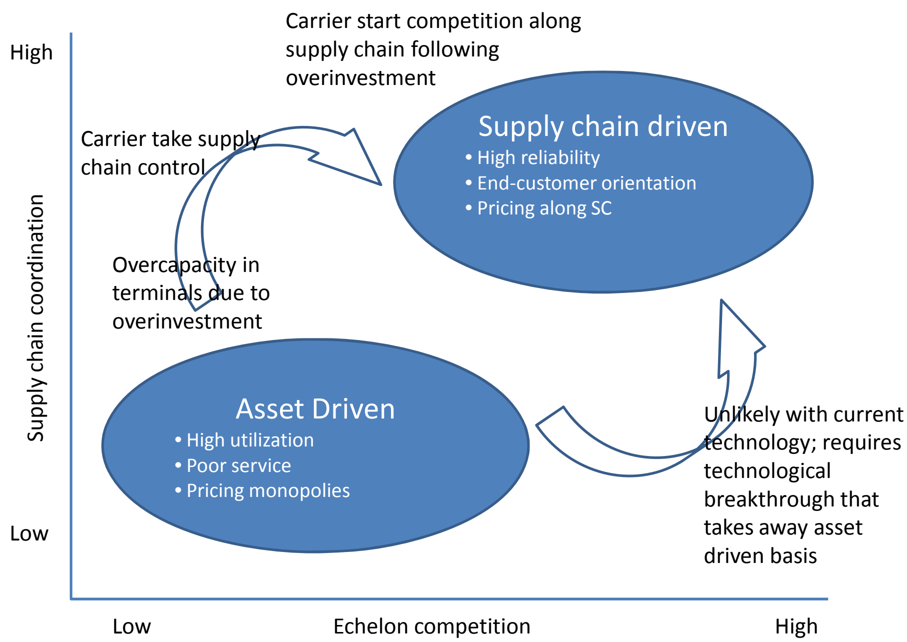

Figure 4. Industry dynamics that may drive the global container shipment industry from an asset driven focus to a supply chain driven focus

Also at the terminals, operations are primarily aimed at the optimization of expensive resources, leading to queuing effects at other places in the supply chain, notably in the hinterland transportation. Current operations are primarily driven by utilizing the scarce assets, while there appears to be little or not attention for an end-to-end supply chain focus. From a supply chain perspective, it would be logical to evaluate the performance of this container supply chain to the actual "delivery reliability" of a particular container at the final point of delivery, at the customer, against a certain total cost towards this customer.

While both modeling and empirical research will need to provide us with the actual insights, we believe that actually only two drivers will enable a true change in focus and performance of this supply chain (see Figure 4). One potential driver could be the period when terminal capacity will be in oversupply, following the extremely high growth in investments in terminals. On the export side, especially in China, there appear to be increasing signals of overcapacity. On the import side in Europe and the US, on the contrary, the growth in capacity has still not been able to keep up with the growth in volume. Also for the ocean liner capacity, the consolidation and alliance formation, coupled with the fact that effectively capacity can be regulated via the speed of the vessels, it is not obvious when this would be the case. An alternative breakthrough could be realized if technology would develop in such a way that scale would be much less important.

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