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Daily Maersk's impacts on shipper's supply chain inventories and implications for the liner shipping industry¹

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ABSTRACT

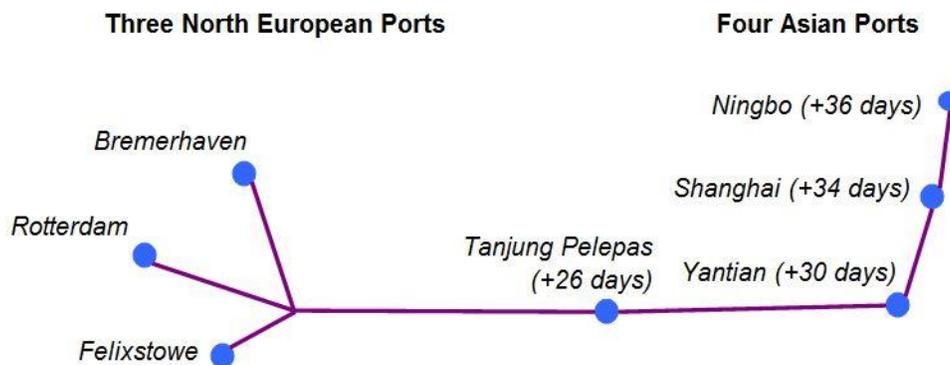
The liner shipping industry has long been characterized by a weekly sailing frequency and schedule unreliability. This research is motivated by the launch of the revolutionary “Daily Maersk” service in late 2011, which introduced daily departures and “absolute reliability” in the Asia–North Europe trade lane. This paper analyzes Daily Maersk’s impacts on a shipper's supply chain inventories and profound implications for the liner shipping industry as a game changer. The quantitative analyses show that the impact of more frequent sailings is most significant on a shipper’s cycle stock, while improving schedule reliability substantially reduces safety stock and pipeline stock. Daily Maersk is most valuable for products that have high value density, high inventory holding cost ratio, low demand variability and high service level requirement. These findings imply that the trend of liner alliance/merger/acquisition is likely to continue or even accelerate as shipping lines consolidate fleet capacity to offer more frequent sailings. Rival carriers may step up their involvement in terminal operations to improve schedule reliability. They also need to rethink about their service level targets and clearly define their preferred customer segments.

Keywords: Daily Maersk; liner shipping; sailing frequency; schedule reliability; supply chain management; maritime supply chain

1. Introduction

The liner shipping industry has long been characterized by weekly departures and schedule unreliability (Vernimmen, Dullaert, and Engelen 2007; Notteboom and Rodrigue 2008). To ship containers more frequently, a shipper often has to engage several ocean carriers that have different departure dates in a week. In this case, a shipper cannot bargain as much discount with any single carrier due to scattered cargo volume. Its logistics management also becomes more complicated, not just because it has to deal with multiple carriers, but also because of their schedule unreliability. According to the statistics provided by Drewry (2010), schedule delay in the container liner shipping industry averaged 32% to 54% from December 2005 to June 2010. Such low schedule reliability makes it very difficult for shippers to practice efficient just-in-time production/distribution (Lam and Van De Voorde 2011). As a result, shippers have to keep more safety stock, or from time to time use more expensive transportation modes to expedite cargoes (Vernimmen, Dullaert, and Engelen 2007).

This study is motivated by the launch of “Daily Maersk” in late 2011 by Maersk Line, the world's largest container shipping company. Daily Maersk serves the Asia–North Europe trade lane. It has daily cut-offs at four Asian ports and guarantees cargo availability after a certain number of days at any one of the three North European ports, as indicated in Figure 1. The service claims “absolute reliability” and promises to pay a penalty for late arrivals (Maersk Line 2011). It sharply contrasts a standard liner shipping service that has a weekly sailing frequency and low schedule reliability.



Source: adapted from Maersk Line (2011)

Figure 1. Daily Maersk port calls and transportation times

Daily Maersk has created a stir in the liner shipping industry. Most shippers have applauded the revolutionary service offering as it helps cut supply chain inventories, which constitute a major cost component in maritime logistics (Leach 2011). Some have even praised Daily Maersk as the most positive initiative coming out of the shipping industry in the past decade (Maersk Line 2011). To counter Daily Maersk, rival carriers have quickly restructured their alliances to offer more frequent sailings on Asia–Europe trade lanes (Barnard 2011; Szakonyi 2011). The shipping market expects more profound changes in the years to come because of Daily Maersk.

This paper analyzes Daily Maersk's impacts on a shipper's supply chain inventories and implications for the liner shipping industry as a game changer. To the best of our knowledge, this is the first scholarly research about Daily Maersk. It is well-established in the literature that maritime transport services should be studied in the context of the supply chain that they are embedded in, as supply chain management is now widely practiced by industry professionals (Robinson 2002; Christopher 2005; Carbone and Gouveral 2007; Cahoon and Notteboom 2008; Zhang and Huang 2012). Many research papers have studied ports from a supply chain perspective, for example, the value propositions and strategic roles of ports/terminals (Robinson 2002; Paixao and Marlow 2003; Robinson 2006; Mangan, Lalwani, and Fynes 2008; Rodrigue and Notteboom 2009; Zhang, Lam, and Huang 2013), port/terminal integration in the supply chain (Carbone and Martino 2003; Panayides and Song 2008; Song and Panayides 2008; Panayides and Song 2009; Tongzon, Chang, and Lee 2009), port performance measurements (Marlow and Paixao 2003; Bichou and Gray 2004), and port competition in supply chain systems (Lam and Yap 2011a, 2011b). Surprisingly, very few papers (Vernimmen, Dullaert, and Engelen 2007; Notteboom and Rodrigue 2008; Saldanha et al. 2009; Lam and Van De Voorde 2011) have adopted a supply chain perspective to study liner shipping services.

This paper aims to narrow the research gap by achieving the following three objectives. First, it performs a case study of Daily Maersk to quantify the impacts of improving sailing frequency and schedule reliability on a shipper's supply chain inventories. Second, it identifies the product segment that Daily Maersk is most valuable to. Third, it discusses the implications of Daily Maersk for the liner shipping industry based on the analytical results and findings. This study offers insights for ocean carriers who strive to deliver superior customer values in a highly competitive business environment.

The rest of this paper is organized as follows. Section 2 reviews relevant literature and defines the analytical methodology in the context of a representative maritime supply chain. Section 3 explains problem settings and data. Section 4 presents case study results and analyses. Section 5 discusses Daily Maersk's implications for the liner shipping industry. Section 6 concludes the research.

2. Methodology

Some transport related studies examined the impact of service attributes on supply chain inventories. Blauwens et al. (2003), Dullaert et al. (2007) and Blauwens et al. (2006) developed analytical models to compare the total logistics costs of using different transport modes and service frequencies at inland transport stage. Bertazzi and Speranza (1997; 1999) built mixed integer programming models to minimize total logistics costs with given transport frequencies. Constable and Whybark (1978) developed a mathematical model and exact and heuristic procedures for jointly determining inventory control policies and transport decisions. Allen et al. (1985) used an analytical model to illustrate the effects of transit time reliability on optimal inventory control policies. Tyworth and Zeng (1998) developed an analytical model to evaluate the effects of transit time performance on logistics cost and service. All these analytical studies showed that improving transport service frequency or reliability allows shippers to reduce supply chain inventories. Several empirical studies also affirmed that service frequency (Zamparini, Layaa, and Dullaert 2011) and reliability (Train and Wilson 2008) are

importance freight transport service attributes. However, their analyses were primarily based on inland transport modes and did not consider the distinctive attributes of liner shipping.

Notteboom (2006) was among the first to highlight the importance of schedule reliability in liner shipping. Ocean carriers' schedule unreliability was identified as a key issue impeding maritime supply chain efficiency (Vernimmen, Dullaert, and Engelen 2007; Notteboom and Rodrigue 2008). Through a simulation study, Saldanha, et al. (2009) suggested that more reliable liner shipping services can render shippers significant inventory cost savings. However, little research has been conducted on the combined effect of improving liner shipping sailing frequency and schedule reliability, which distinguishes Daily Maersk from a standard service.

Adapting the works of (Allen, Mahmoud, and McNeil 1985; Tyworth and Zeng 1998; Blauwens et al. 2003; Blauwens et al. 2006; Dullaert et al. 2007; Saldanha et al. 2009), we develop an analytical model to calculate inventories required in a shipper's maritime supply chain. The analytical model provides a theoretical basis to quantify the inventory cost savings that Daily Maersk can deliver for its customers. It considers three types of inventories: pipeline stock, cycle stock and safety stock. Pipeline stock refers to inventories that are in-transit at various transport stages. Cycle stock at the receiving location is the portion of inventory available for the average demand during cargo arrival intervals. Safety stock at the receiving location is used to cover demand variations (Liberatore and Miller 1995; Coyle, Bardi, and Langley 2009). The following notations are defined.

- V = value of a container load in a twenty-foot equivalent unit (TEU) (USD)
- D = demand per day, a random variable with mean μ_D and standard deviation σ_D (TEUs per day)
- $CovD$ = coefficient of variation of demand (σ_D / μ_D)
- R = annual demand (TEUs)
- Q = shipment size (TEUs)
- h_i = holding cost ratio for pipeline stock (percent per year)
- h_w = holding cost ratio for cycle and safety stocks (percent per year)
- L = door to door transport lead time, a random variable with mean μ_L and standard deviation σ_L (days)
- K = safety stock factor corresponding to a pre-specified service level target
- s = number of sailings per week

This study considers a hypothetical but representative case of liner shipping from Shenzhen Yantian port in China to the port of Rotterdam in Netherlands. The case involves a manufacturer seller, a buyer (shipper) and an ocean carrier. The seller exports containerized cargoes based on Incoterms Ex Works (EXW) from Dongguan, Guangdong province, China. Note that several other Incoterms are also widely used in maritime transport, for example, Free on Board (FOB), and Cost, Insurance and Freight (CIF) (Cahoon and Notteboom 2008). This case study chooses EXW trade term as it gives a shipper most control over a maritime supply chain, and therefore allows the quantitative analyses to unveil the impacts of Daily Maersk more completely. The buyer has a

regional warehouse about 2 hours trucking distance from the port of Rotterdam. The buyer has a contract with the ocean carrier to ship all cargoes from the seller to the regional warehouse. On average, the buyer has more than one container to transport each day and all products are shipped in full containers. Order processing cost is not considered in the analyses as it is often a very small portion of total logistics cost (Saldanha et al. 2009).

Average pipeline stock (PS) is calculated as (Leachman 2008)

$$PS = \frac{R\mu_L}{365} = \mu_D\mu_L \quad (1)$$

On average, half of the shipment size is in cycle stock (CS) (Blauwens et al. 2003):

$$CS = \frac{Q}{2} \quad (2)$$

A year is approximately 52 weeks. The buyer ships containers regularly according to the sailing frequency of the ocean carrier to minimize cycle stock. Equation (2) can be rewritten as follows:

$$CS = \frac{R}{2 \times 52s} = \frac{7\mu_D}{2s} \quad (3)$$

Broadly speaking, there are three approaches for setting safety stocks, namely the “time supply” approach, the “shortage costing” approach and the “service level” approach (Silver, Pyke, and Peterson 1998). The first approach sets safety stock equal to a certain time of supply. In reality, some shippers keep more than one week safety stock because of the schedule unreliability of liner shipping services. However, if we follow this approach, the results may exaggerate the benefits of Daily Maersk. The second approach minimizes the total of shortage cost and inventory holding cost. This approach is difficult to implement in practice because it is usually hard to quantify shortage costs (Vernimmen, Dullaert, and Engelen 2007). The third approach bypasses the problem. It minimizes inventory holding cost subject to a service level target.

The analytical methodology adopted in this paper follows the “service level” approach to calculate safety stock. It measures service level as the probability of no stock-out per replenishment cycle. An alternative service measure is fill rate, i.e. a fraction of demand to be satisfied from stock on hand. These two service measures lead to different formulations for safety stock calculation. This study employs the first service measure as it is most often used in practice (Dullaert et al. 2007).

To compute safety stock, it is essential to first derive the standard deviation of demand during lead time (DDLT). We assume that lead time is independent of demand and demand itself is not auto-correlated (Vidal and Goetschalckx 2000). In this case, the standard deviation of DDLT can be computed as follows (Silver, Pyke, and Peterson 1998; Vernimmen, Dullaert, and Engelen 2007):

$$\sigma_{DDLT} = \sqrt{\mu_L\sigma_D^2 + \mu_D^2\sigma_L^2} = \sqrt{\mu_L\mu_D^2CovD^2 + \mu_D^2\sigma_L^2} = \mu_D\sqrt{\mu_LCovD^2 + \sigma_L^2} \quad (4)$$

After obtaining the standard deviation of DDLT, the level of safety stock (SS) corresponding to a pre-specified service level target can be calculated as follows:

$$SS = K\sigma_{DDL T} = K\mu_D\sqrt{\mu_L CovD^2 + \sigma_L^2} \quad (5)$$

Assuming demand follows a normal distribution, the value of K can be easily obtained from any statistical handbook. For example, the value of K corresponding to a stock-out risk of 5% (i.e. 95% service level) is equal to 1.64. It means that a safety stock of 1.64 times the standard deviation of DDLT is required to ensure a 95% service level. For service levels of 97% and 99%, their corresponding K factors amount to 1.88 and 2.33 respectively (Blauwens et al. 2003). Note that the values of K may be different for demand patterns not following a normal distribution, for example, Erlang and Poisson distributions. However, equation (5) is still applicable for the calculation of safety stock. Based on equations (1), (3) and (5), the quantity of total supply chain inventories (SCIQ) can be obtained by summarizing pipeline stock, cycle stock and safety stock.

$$SCIQ = \mu_D\mu_L + \frac{7\mu_D}{2s} + K\mu_D\sqrt{\mu_L CovD^2 + \sigma_L^2} \quad (6)$$

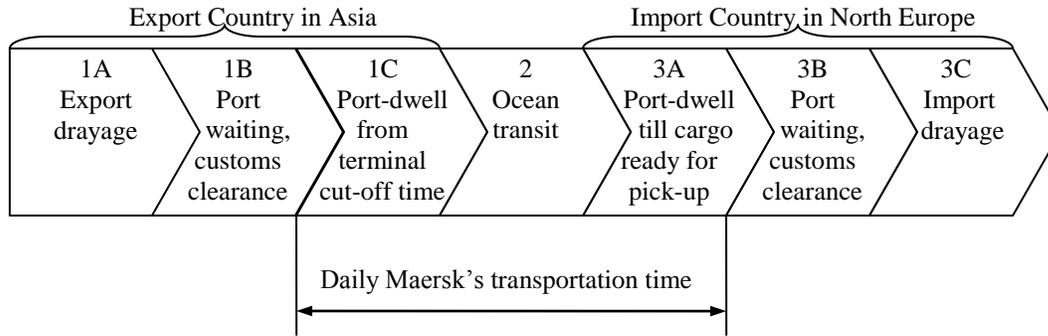
The cost of holding these supply chain inventories (SCIC) can be calculated as follows:

$$SCIC = \mu_D\mu_L h_i V + \left(\frac{7\mu_D}{2s} + K\mu_D\sqrt{\mu_L CovD^2 + \sigma_L^2}\right) h_w V \quad (7)$$

From equations (6) and (7), it can be observed that supply chain inventories are linear to μ_D . This implies that demand volume can be filtered if we measure inventories by days of demand.

3. Problem settings and data

Figure 2 illustrates door-to-door transport lead time segments for a marine container shipped from Asia to North Europe. The total transport lead time is partitioned into seven segments. The seven segments can be grouped into three transport stages: at export country in Asia (stage 1), in ocean transit (stage 2), and at import country in North Europe (stage 3). A standard liner shipping service gives scheduled ocean transit time, while Daily Maersk guarantees transportation time. Maersk Line (2011) defines transportation time as the time taken from the container terminal cut-off at origin until the cargo becomes available for pick-up at destination. In contrast, ocean transit time only includes the time from when vessel departs at origin until it arrives at destination.



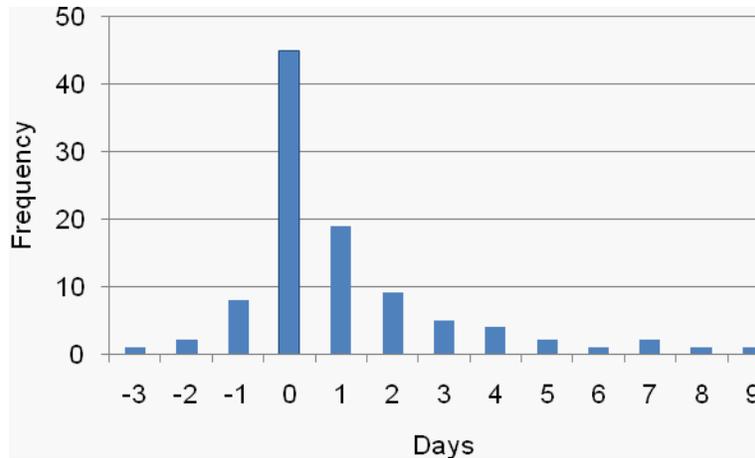
Source: adapted from Saldanha, et al. (2009)

Figure 2. A maritime container's door-to-door transport lead time segments

This research defines the following liner shipping services with different sailing frequencies and schedule reliability. Sailing frequency is based on the number of departures from a same port. Schedule reliability is defined as the percentage of times that a ship arrives at a port on the scheduled day or on the day immediately before the scheduled day of arrival (Drewry 2010). Service I represents a standard service that has a weekly sailing frequency. Its schedule reliability is 70%, the industry average in late 2011 when Daily Maersk was launched (Drewry 2012). Service II only improves sailing frequency to daily. Service III only improves schedule reliability to 99%, which is the service level that Daily Maersk achieved in the first two months of its official operation (Maersk Line 2011). Daily Maersk improves not only sailing frequency but also schedule reliability.

- Service I: weekly sailings, 70% schedule reliability
- Service II: daily sailings, 70% schedule reliability
- Service III: weekly sailings, 99% schedule reliability
- Daily Maersk: daily sailings, 99% schedule reliability

According to a detailed survey of Drewry (2010), Figure 3 shows the pattern of ocean transit time in liner shipping. A histogram is used to approximate the transit time distribution, with the horizontal axis representing days of deviation from schedule and the vertical axis representing occurrence frequency. Following the format used in (Saldanha et al. 2009), the histogram can be described numerically as "Histogram Min = -3, Max = 9, Freq = {1, 2, 8, 45, 19, 9, 5, 4, 2, 1, 2, 1, 1}" . In numerical expression, the values of "Min" and "Max" set the lower and upper bounds of transport lead time measured in days. The values of "Freq", a set of numbers in the bracket, represent the occurrence frequencies of various transport lead times that equally divide the transport lead time range.



Source: Drawn by authors based on data from Drewry (2010)

Figure 3. Number of days deviation from scheduled day of arrival

For liner shipping services that have different schedule reliability, we assume their days of early/delayed arrival follow a similar pattern as depicted in Figure 3. Ocean transit time distribution for Services I and II, whose schedule reliability is 70%, can be approximated as “Histogram Min = 24, Max = 34, Freq = {2, 10, 60, 12, 6, 3, 3, 1, 1, 1}”. Based on the histogram approximation, it is easy to calculate their ocean transit time as 26.57 days on average with a variance of 2.73 days². Similarly, Service III's ocean transit time distribution is approximated as “Histogram Min = 25, Max = 27, Freq = {15, 84, 1}”. The average ocean transit time is 25.86 days with a variance of 0.14 days². Daily Maersk's transportation time distribution is approximated as “Histogram Min = 29, Max = 31, Freq = {15, 84, 1}”. Its average value is 29.86 days with a variance of 0.14 days².

Data on inland transport lead times were estimated in consultation with an established freight forwarder that has customers shipping via Shenzhen Yantian port regularly. The freight forwarder is believed to be unbiased because it is neutral and is not affiliated with any shipping lines including Maersk Line. Although secondary data are not available for the validation of detailed segment lead times, total inland transport lead times at import and export ends are found to be in line with those reported in the recent literature (Saldanha, Russell, and Tyworth 2006; Leachman 2008). The appendix gives detailed data for histogram approximation.

Table 1 summarizes all transport lead time means (the first numbers in brackets) and variances (the second numbers in brackets). According to the illustration in Figure 2, the maritime supply chain includes three transport stages. Assuming their lead times are independent from each other, the mean and variance of total transport lead time are the sum of those of the three transport stages.

Table 1. Data of transport lead time means and variances

Transport stage 1	Transport stage 2	Transport stage 3	Total transport lead time
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Service I	(4.70, 1.04)	(26.57, 2.73)	(2.50, 0.55)	(33.77, 4.32)
Service II	(3.25, 0.33)	(26.57, 2.73)	(2.50, 0.55)	(32.32, 3.61)
Service III	(4.43, 0.51)	(25.86, 0.14)	(2.50, 0.55)	(32.79, 1.20)
Daily Maersk	(0.44, 0.08)	(29.86, 0.14)	(1.53, 0.49)	(31.82, 0.71)

Note: For Daily Maersk, transport stage 1 includes only segments 1A and 1B as illustrated in Figure 2. Its transport stage 2 includes segments 1C, 2 and 3A, and transport stage 3 includes segments 3B and 3C.

Port-of-departure dwell time is influenced by factors including carriers' cut-off time requirements, sailing frequency, vessel schedule reliability and customs clearance. Carriers often require shippers to deliver containers to a port-of-departure at least two days before the booked vessel's scheduled arrival. Table 1 shows that improving sailing frequency reduces both the mean and variance of port-of-departure dwell time. This is because shippers tend to keep longer buffer time when sailings are infrequent as missing a vessel may result in long waiting time for the next available vessel. To further reduce the variance of port-of-departure dwell time, however, schedule reliability must be improved. This is because schedule unreliability is a cause of port-of-departure dwell time variability. Besides vessel arrival delays, uncertainties associated with customs clearance play a key part to prolong port-of-departure dwell time. In mainland China, export containers must arrive one day in advance for customs clearance and inspection. In the case of open-box inspection, actual time taken might be up to two days or even more. For this reason, freight forwarders often require cargo owners to deliver containers two to three days earlier than ocean carriers' terminal cut-off times. This causes port-of-departure dwell time to typically take four to five days in China if there is no delay of vessel arrival. At the port-of-entry, it is assumed that port dwell time is not affected by liner's schedule unreliability.

In the base case scenario, the coefficient of variance of demand ($CovD$) is set as 0.075. Such a demand variance means that approximately 95% of random daily demands would fall within $\pm 15\%$ of the mean for a bell-shaped distribution (Saldanha et al. 2009). Holding cost ratio for cycle and safety stocks (h_w) is conservatively set as 20% per year (Huang, Zhang, and Liang 2005; Leachman 2008). In all scenarios, holding cost ratio h_i for pipeline stock is set as 10% lower than h_w because pipeline stock does not incur warehousing cost (Saldanha et al. 2009).

4. Results and analyses

4.1. Impacts of improving sailing frequency and schedule reliability

This section employs the methodology defined in Section 2 to quantify the impacts of improving liner shipping sailing frequency and schedule reliability. As mentioned previously, a superior transport service allows a shipper to reduce supply chain inventories. Table 2 shows required supply chain inventories calculated based on equations (1), (3), (5) and (6). The definitions of liner shipping services follow those given in Section 3. The shipper is assumed to keep a 97% service level (SL).

Table 2. Supply chain inventories (measured by days of demand)

	Service I	Service II	Service III	Daily Maersk
Cycle stock	3.50	0.50	3.50	0.50
Pipeline stock	33.77	32.32	32.79	31.82
Safety stock (SL=97%)	3.99	3.66	2.21	1.77
Total Inventory (SL=97%)	41.26	36.48	38.5	34.09

It is apparent that cycle stocks are the lowest for Service II and Daily Maersk because of their daily sailings. In comparison with a standard weekly service, daily sailings allow a shipper to transport cargoes in much smaller batches. Consequently, cycle stock can be reduced from 3.5 to 0.5 days.

Pipeline stock measured by days of demand is equal to the mean of total transport lead time. Due to long transit time in maritime logistics, pipeline stock is the largest component of supply chain inventories. For the service types included in Table 2, considerable differences can be observed in the required pipeline stocks. In comparison with a standard service, Service II reduces pipeline stock from 33.77 to 32.32 days. This is because shippers no longer need to keep as much buffer time at port-of-departure when the consequence of missing a booked vessel is less severe with more frequent sailings. Improving schedule reliability, Service III can reduce pipeline stock to 32.79 days because of less transport delays. Daily Maersk leads to the lowest pipeline stock of 31.82 days because of the combined effect of improved sailing frequency and schedule reliability. Although it is not within the scope of this study, it should be acknowledged that shippers' pipeline stocks have been adversely affected by carriers' implementation of slow steaming in recent years.

Safety stock is only marginally reduced by improving sailing frequency alone from weekly (Service I) to daily (Service II). This is because more frequent sailings lead to lower variance of port-of-departure dwell time. However, the variance of port-of-departure dwell time cannot be much reduced due to ocean vessels' low schedule reliability. As mentioned previously, schedule unreliability is a major cause of prolonged port-of-departure dwell time. Improving schedule reliability alone from 70% (Service I) to 99% (Service III) can reduce safety stock from 3.99 to 2.21 days. Daily Maersk further reduces safety stock requirement to 1.77 days by improving both sailing frequency and schedule reliability.

In summary, the impact of more frequent sailings is most significant on cycle stock, followed by pipeline stock and safety stock. Improving schedule reliability reduces safety stock and pipeline stock, but has no impact on cycle stock. Daily Maersk, which improves both sailing frequency and schedule reliability, can reduce all three supply chain stocks significantly, and thus achieve maximal inventory reductions.

Table 3. Supply chain inventory cost savings over a standard service

	Service II	Service III	Daily Maersk
SL=95%	16.8%	8.6%	24.8%

SL=97%	16.6%	9.3%	25.4%
SL=99%	16.3%	10.7%	26.6%

Table 3 compares supply chain inventory cost savings resulting from improving sailing frequency or/and schedule reliability. Inventory costs are calculated based on equations (7). In comparison with a standard service (Service I), daily sailings (Service II) can help cut inventory costs by 16.6% when the shipper keeps a 97% service level. If the sailing frequency is unchanged as weekly, improving schedule reliability from 70% (Service I) to 99% (Service III) can save inventory costs by 9.3%. Daily Maersk can enable much greater inventory cost savings of 25.4%.

A shipper's service level target influences potential inventory cost savings. Table 3 shows that when a shipper sets a higher service level target, Services II delivers slightly less percent savings. In contrast, Services III and Daily Maersk can achieve greater percent savings. This is because a larger portion of safety stock is required at a higher service level to cover demand and transport lead time variations. Service II is disadvantaged at a higher service level as it does not directly tackle schedule unreliability, as in the case of Service III and Daily Maersk.

It is worthwhile to take note that the involvement of multiple stakeholders and authorities causes the maritime supply chain to become very fragmented, which is reflected in the many lead time segments as illustrated in Figure 1. Consequently, shippers suffer from high inventory costs. To fully integrate the maritime supply chain, not only shipping lines, terminal operators, shippers, freight forwarders and inland transport service providers must work together, but also port authorities and customs. Shipping lines have been extending upstream and downstream chain control (Notteboom and Rodrigue 2008). However, a portion of inventory costs in the maritime supply chain will remain fixed due to customs and government regulations unless they are simplified and relevant procedures are streamlined.

4.2. Shipping rate premiums

Table 4. Daily Maersk's shipping rate premiums

Product value/TEU	\$10,000	\$50,000	\$90,000	\$130,000	\$170,000
Holding cost ratio h_w					
20%	\$34	\$170	\$306	\$441	\$577
40%	\$73	\$366	\$659	\$952	\$1,245
60%	\$113	\$563	\$1,013	\$1,463	\$1,914

Table 4 presents Daily Maersk's shipping rate premiums in relation to product value density and holding cost ratio h_w . Shipping rate premium is defined as equal to the inventory cost savings resulting from the use of a superior service in comparison with a standard service (Saldanha et al. 2009). Rate premiums serve as a gauge how much more an ocean carrier could charge, or a shipper may be willing to pay, for a superior liner

service. It is measured by USD per TEU. For a fully loaded forty-foot container, the amount of rate premium should double. The service level requirement of shippers is assumed to be 97%.

It is apparent that Daily Maersk's shipping rate premiums vary substantially by product value density and holding cost ratio. Note that these two parameters are largely determined by product nature (Lovell, Saw, and Stimson 2005). Industrial raw materials and commodity-type products often have a low holding cost ratio of about 20%. However, the ratio may be much higher for perishable, fashionable and electronic products that have a short product life cycle (Leachman 2008). For a product that has a low value of \$10,000 per TEU, Daily Maersk's rate premiums are insignificant. However, for products whose values are \$90,000 and \$170,000 per TEU, the rate premiums amount to \$306 and \$577 respectively when the holding cost ratio is 20%. In the case of a 60% holding cost ratio, which may be applicable for dairy products and consumer electronics, Daily Maersk's rate premiums are equal to \$1,013 and \$1,914 respectively.

The inventory cost savings of improving sailing frequency and schedule reliability, as quantified above for the case of Daily Maersk, have been supported by evidences in the industry. According to Page (2010), many shippers have now made their priorities clear to ocean carriers: service, reliability and price, in that order. Near to the one year anniversary of Daily Maersk, Maersk Line (2012) conducted a survey of 175 customers. Most of them stated that they had saved either time or money. 42% responded that they had saved logistics costs as a direct result of using Daily Maersk. The benefits are especially substantial and tangible for products that have high value density and high inventory holding cost ratio. A specific product example is laptop computers, which are of high values and whose values quickly depreciate over time as new and improved products continuously hit the market (Rao 2012).

4.3. Sensitivity analysis of demand variance

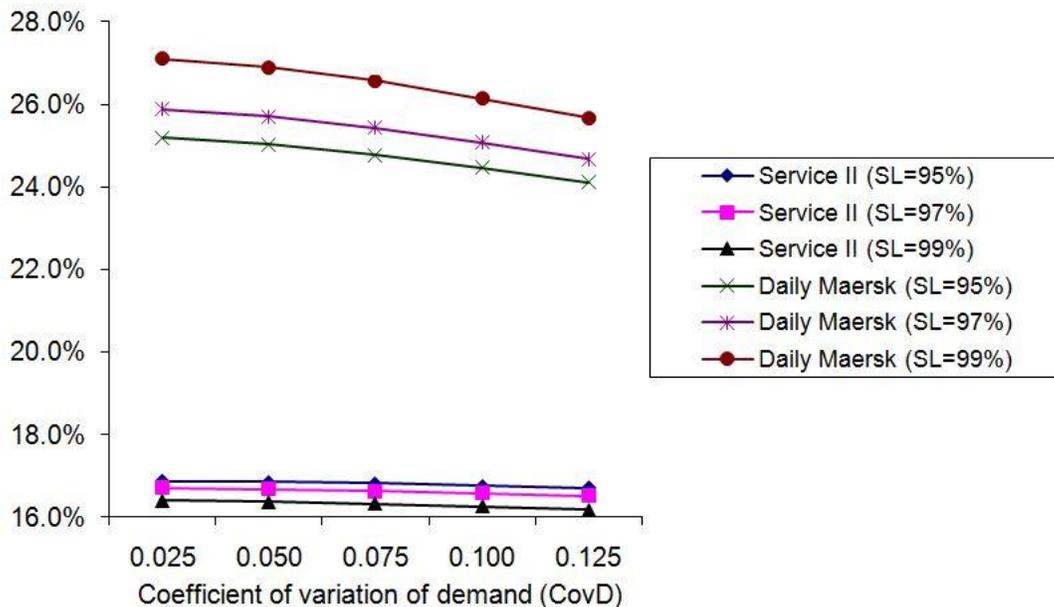


Figure 4. Supply chain inventory cost savings over a standard service

Figure 4 presents the results of sensitivity analysis of demand variance. It is less beneficial to use Daily Maersk when demand variance is greater. This is because more safety stock is required to ensure the same service level when demand variance increases. This undermines the comparative advantage of Daily Maersk as safety stock reduction is one of its key benefits. Service II is not sensitive to changes in demand variance, because safety stock reduction only makes marginal contributions to its inventory cost savings. Nevertheless, wide gaps still exist between Daily Maersk's and Service II's inventory cost savings. This finding is in line with that of Saldanha, *et al.* (2009). They suggested that cost savings resulted from transit time reliability would not disappear until CovD approaches 2.0, which is very rare. Consistent with the findings presented in Section 4.1, Daily Maersk is more beneficial for products that have a higher service level requirement.

5. Implications for the liner shipping industry

Based on the results and analyses presented above, we can advance two general propositions. The first general proposition is that increasing sailing frequency can help shippers reduce cycle stock most significantly, followed by pipeline stock and safety stock. Improving schedule reliability helps substantially reduce safety stock and pipeline stock, but has not impact on cycle stock. Maximal inventory cost savings can only be achieved by improving both sailing frequency and schedule reliability, as in the case of Daily Maersk. The second general proposition is that Daily Maersk is most valuable for products that have high value density, high inventory holding cost ratio, low demand variability and high service level requirement. There are several implications that can be derived from these general propositions for the liner shipping industry.

First, it is indeed necessary for rival carriers to improve sailing frequency to compete against Daily Maersk. More frequent sailings offered by rival carriers are supported by two important changes in their alliance structure to consolidate fleet capacities. One change was the birth of the G6 Alliance from merging the New World Alliance (NOL/APL, MOL, HMM) and the Grand Alliance (Hapag-Lloyd, NYK, OOCL). Another change was the establishment of the MSC/CMA CGM Alliance. As a result of these two changes, 90% market share in the Far East/Europe route is now controlled by the big four powers (Moon 2012), namely Maersk Line, the G6 Alliance, the MSC/CMA CGM Alliance and the CKYH Alliance (COSCO, K-Line, Yang Ming, Han Jin). This shows that Daily Maersk is indeed a market-changing service. With shippers' expectation now being raised to more frequent sailings, the trend of liner alliance/merger/acquisition (Midoro and Pitto 2000; Slack, Comtois, and McCalla 2002; Lam, Yap, and Cullinane 2007) is likely to continue or even accelerate.

Second, it is crucial for carriers to improve schedule reliability to enable shippers further reduce supply chain inventories. However, it would be more challenging to improve schedule reliability than to increase sailing frequency. Schedule unreliability has been mainly caused by factors uncontrollable to carriers, for example, port/terminal congestion, port/terminal productivity below expectations (Notteboom 2006). To secure capacity in key ports in their service schedules, carriers have become increasingly involved in terminal operations. Just to name a few, Maersk Line, MSC, CMA CGM,

COSCO and Evergreen have all been very active in making strategic investment in container terminals (Slack and Fremont 2005; Notteboom 2006; Vernimmen, Dullaert, and Engelen 2007; Pawlik et al. 2011). In the case of Maersk Line, its parent company AP Moller-Maersk operates a large number of container terminals worldwide through its subsidiary APM Terminals (Vernimmen, Dullaert, and Engelen 2007). This enables Maersk Line to use a global network of dedicated hub terminals (Fremont 2007) to achieve the highest schedule integrity in the liner shipping industry (Notteboom and Rodrigue 2008). As Daily Maersk attracts shippers by a very high service level, rival carriers may step up their involvement in terminal operations to improve schedule reliability.

Third, the rate premium of Daily Maersk is much more significant for products that have high value density, high inventory holding cost ratio, low demand variation and high service level requirement. This implies that market segmentation has become important in the liner shipping industry. In the past, most shippers regarded all liner services as identical (Saldanha et al. 2009) and the industrial competition focused on cost. To a large extent, the liner shipping industry ignored customer value creation in other areas, for example, transit time and service quality (Robinson 2006; Lee and Song 2010). As Daily Maersk breaks the industrial norm, shippers have quickly recognized the value of more frequent sailings and schedule reliability. Rival carriers now have to rethink about their service level targets and the strategic positioning of their service offerings.

In summary, Daily Maersk has made profound impact on the liner shipping industry. In the Asia–Europe trade lane, industrial competition has been much intensified since the announcement of Daily Maersk. Although Maersk Line did not give a time line, it stated that similar services should be rolled out worldwide. When that happens, the global liner shipping industry may be profoundly reshaped. Coupled with overcapacity issues caused by sluggish demand, the liner shipping industry may face a big reshuffle in the years to come.

6. Conclusions

This paper employs a supply chain perspective to analyze Daily Maersk’s impacts on a shipper’s inventory management and its implications for the liner shipping industry. In the past few decades, a standard liner shipping service has had a weekly sailing frequency and low schedule reliability. In late 2011, Maersk Line launched its market-changing Daily Maersk service that offers a daily sailing frequency and promises “absolute reliability” in the Asia–North Europe trade lane. Daily Maersk has quickly gained popularity among shippers as it helps significantly reduce supply chain inventories, which constitute a major cost component in maritime logistics. To prevent loss of market share, rival carriers have quickly changed their alliance structure to provide more frequent sailings. In light of the far-reaching impact of Daily Maersk, this paper quantifies Daily Maersk’s impacts on a shipper’s supply chain inventories and discusses its profound implications for the liner shipping industry.

This paper makes several important contributions. First, it is believed to be the first research study about Daily Maersk. Daily Maersk is revolutionary and has been regarded

as among the most positive initiative coming out of the liner shipping industry in the past decade. It warrants further study. Second, it employs a supply chain perspective to quantify Daily Maersk's benefits, which are evidential in a shipper's inventory cost savings. So far, limited research has adopted a supply chain perspective to study liner shipping services. Third, the analytical results show that increasing sailing frequency helps reduce cycle stock most significantly, followed by pipeline stock and safety stock, while improving schedule reliability helps reduce safety stock and pipeline stock. For the representative case given in the study, increasing sailing frequency from weekly to daily can help cut supply chain inventory costs by 16.6%. If schedule reliability is also improved to 99% as in the case of Daily Maersk, inventory cost savings could amount to 25.4%. Fourth, the analyses identify that Daily Maersk is most valuable for products that have high value density, high inventory holding cost ratio, low demand variance and high service level requirement. Last but not least, it discusses the implications of Daily Maersk for the liner shipping industry. The trend of liner alliance/merger/acquisition is likely to continue or even accelerate. Rival carriers may need to become more involved in terminal operations to improve their schedule reliability. They also have to rethink about their service level targets and the strategic positioning of their service offerings.

This research has its limitations. The quantitative analyses conducted in this paper are theoretical. Although the quantified benefits are believed to be conservative and realistic, shippers need to implement appropriate inventory control policies to realize the potential inventory cost savings. It would be beneficial to conduct a comprehensive empirical study to validate actual inventory cost savings of shippers who have switched to Daily Maersk. In addition, we are extending the research to analyze the implications of Daily Maersk for the port industry.

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References

- Allen, W. Bruce, Mohamed M. Mahmoud, and Douglas Mcneil. 1985. The Importance of Time in Transit and Reliability of Transit Time for Shippers, Receivers, and Carriers. *Transportation Research Part B* 19B (5): 447-456.
- Barnard, Bruce. 2011. "Maersk Adds Three European Ports to Daily Maersk." *The Journal of Commerce*. Accessed 15 February 2012. <http://www.joc.com/container-lines/maersk-adds-three-european-ports-daily-maersk>.
- Bertazzi, Luca, and Maria Grazia Speranza. 1999. Inventory Control on Sequences of Links with Given Transportation Frequencies. *International Journal of Production Economics* 59 (1-3): 261-270.
- Bertazzi, Luca, and Maria Grazia Speranza. 1997. Minimization of Logistic Costs with Given Frequencies. *Transportation Research Part B* 31 (4): 327-340.

- Bichou, Khalid, and Richard Gray. 2004. A Logistics and Supply Chain Management Approach to Port Performance Measurement. *Maritime Policy & Management* 31 (1): 47-67.
- Blauwens, G., S. Janssens, B. Vernimmen, and Frank Witlox. 2003. "A Logistical Analysis of Transport Frequency." In *Across the Border: Building Upon a Quarter Century of Transport Research in the Benelux*, edited by Dullaert, W., Bart A.M. Jourquin and Jacob B. Polak, 69-88. Antwerp, Belgium: De Boeck
- Blauwens, Gust, Nico Vandaele, Eddy Van De Voorde, Bert Vernimmen, and Frank Witlox. 2006. Towards a Modal Shift in Freight Transport? A Business Logistics Analysis of Some Policy Measures. *Transport Reviews* 26 (2): 239-251.
- Cahoon, Stephen, and Theo E. Notteboom. 2008. "Port Marketing Tools in a Logistics Restructured Market Environment: The Quest for Port Royalty." *Paper presented at the Proceedings of the 2008 International Association of Maritime Economists (IAME) Conference*, 1-19, Dalian, China, April.
- Carbone, Valentina, and Marcella De Martino. 2003. The Changing Role of Ports in Supply-Chain Management: An Empirical Analysis. *Maritime Policy & Management* 30 (4): 305-320.
- Carbone, Valentino, and Elisabeth Gouvernal. 2007. "Supply Chain and Supply Chain Management: Appropriate Concepts for Maritime Studies." In *Ports, Cities, and Global Supply Chains*, edited by Wang, James, Daniel Olivier, Theo E. Notteboom and Brian Slack, 11-26. Burlington: Ashgate
- Christopher, Martin. 2005. *Logistics and Supply Chain Management: Creating Value-Adding Networks*. 3rd ed. New York: Financial Times Prentice Hall.
- Constable, Gordon K., and D. Clay Whybark. 1978. The Interaction of Transportation and Inventory Decisions. *Decision Sciences* 9 (4): 688-699.
- Coyle, John J., Edward J. Bardi, and C. John Langley. 2009. *Supply Chain Management: A Logistics Perspective*. Canada: South-Western Cengage Learning.
- Drewry. 2010. *Schedule Reliability Insight Q3 2010*. London: Drewry Shipping Consultants.
- Drewry. 2012. *Carrier Performance Insight April 2012*. London: Drewry Shipping Consultants.
- Dullaert, Wout, Bert Vernimmen, El-Houssaine Aghezzaf, and Birger Raa. 2007. Revisiting Service-Level Measurement for an Inventory System with Different Transport Modes. *Transport Reviews* 27 (3): 273-283.
- Fremont, A. 2007. Global Maritime Networks: The Case of Maersk. *Journal of Transport Geography* 15 (6): 431-442.
- Huang, George Q., X. Y. Zhang, and L. Liang. 2005. Towards Integrated Optimal Configuration of Platform Products, Manufacturing Processes, and Supply Chains. *Journal of Operations Management* 23: 267-290.
- Lam, Jasmine Siu Lee, and Eddy Van De Voorde. 2011. Scenario Analysis for Supply Chain Integration in Container Shipping. *Maritime Policy & Management* 38 (7): 705-725.
- Lam, Jasmine Siu Lee, and Wei Yim Yap. 2011a. Container Port Competition and Complementarity in Supply Chain Systems: Evidence from the Pearl River Delta. *Maritime Economics and Logistics* 13 (2): 102-120.

- Lam, Jasmine Siu Lee, and Wei Yim Yap. 2011b. Dynamics of Liner Shipping Network and Port Connectivity in Supply Chain Systems: Analysis on East Asia. *Journal of Transport Geography* 19 (6): 1272-1281.
- Lam, Jasmine Siu Lee, Wei Yim Yap, and Kevin Cullinane. 2007. Structure, Conduct and Performance on the Major Liner Shipping Routes. *Maritime Policy & Management* 34 (4): 359-381.
- Leach, Peter T. 2011. "Rival Carriers Ready Response to Daily Maersk." *The Journal of Commerce*. Accessed 15 February 2012. <http://www.joc.com/rival-carriers-ready-response-daily-maersk>.
- Leachman, Robert C. 2008. Port and Modal Allocation of Waterborne Containerized Imports from Asia to the United States. *Transportation Research Part E* 44 (2): 313-331.
- Lee, Eon-Seong, and Dong-Wook Song. 2010. Knowledge Management for Maritime Logistics Value: Discussing Conceptual Issues. *Maritime Policy & Management* 37 (6): 563-583.
- Liberatore, Matthew J., and Tan Miller. 1995. A Decision Support Approach for Transport Carrier and Mode Selection. *Journal of Business Logistics* 16 (2): 85-115.
- Lovell, Antony, Richard Saw, and Jennifer Stimson. 2005. Product Value-Density: Managing Diversity through Supply Chain Segmentation. *International Journal of Logistics Management* 16 (1): 142-158.
- Maersk Line. 2011. "Daily Maersk: Introducing Absolute Reliability." Accessed 15 February 2012. <http://www.dailymaersk.com/>.
- Maersk Line. 2012. "Daily Maersk: Celebrating One Year of Reliability." Accessed 11 January 2013. http://www.maerskline.com/link/?page=news&path=/news/story_page/12/D_Maersk.
- Mangan, John, Chandra Lalwani, and Brian Fynes. 2008. Port-Centric Logistics. *International Journal of Logistics Management* 19 (1): 29-41.
- Marlow, Peter B., and Ana C. Paixao. 2003. Measuring Lean Ports Performance. *International Journal of Transport Management* 1 (4): 189-202.
- Midoro, Renato, and Alessandro Pitto. 2000. A Critical Evaluation of Strategic Alliances in Liner Shipping. *Maritime Policy & Management* 27 (1): 31-40.
- Moon, Daniel S. H. 2012. "What's Next?" Accessed 8 April 2012. <http://www.cee.ntu.edu.sg/Events/Pages/MaritimeEvents.aspx>.
- Notteboom, Theo E. 2006. The Time Factor in Liner Shipping Services. *Maritime Economics and Logistics* 8 (1): 19-39.
- Notteboom, Theo E., and Jean-Paul Rodrigue. 2008. Containerisation, Box Logistics and Global Supply Chains: The Integration of Ports and Liner Shipping Networks. *Maritime Economics and Logistics* 10 (1-2): 152-174.
- Page, Paul. 2010. "Reality Shows." *The Journal of Commerce*. Accessed 10 January 2013. http://www.joc.com/reality-shows_20101210.html.
- Paixao, Ana Cristina, and Peter Bernard Marlow. 2003. Fourth Generation Ports--a Question of Agility? *International Journal of Physical Distribution & Logistics Management* 33 (4): 355-376.
- Panayides, P. M., and D. W. Song. 2008. Evaluating the Integration of Seaport Container Terminals in Supply Chains. *International Journal of Physical Distribution & Logistics Management* 38 (7): 562-584.

- Panayides, Photis M., and Dong-Wook Song. 2009. Port Integration in Global Supply Chains: Measures and Implications for Maritime Logistics. *International Journal of Logistics: Research & Applications* 12 (2): 133-145.
- Pawlik, T., L. Stemmler, A. J. Baird, and M. Helch. 2011. The Value of Container Terminal Investment to Ocean Carrier Strategy. *Maritime Economics & Logistics* 13 (3): 319-341.
- Rao, Ramadas. 2012. "Reliability Bugle Sounded." Accessed 10 January 2013. http://www.maritimegateway.com/mgw/index.php?option=com_content&view=article&id=530:rel.
- Robinson, Ross. 2002. Ports as Elements in Value-Driven Chain Systems: The New Paradigm. *Maritime Policy & Management* 29 (3): 241-255.
- Robinson, Ross. 2006. Port-Oriented Landside Logistics in Australian Ports: A Strategic Framework. *Maritime Economics & Logistics* 8 (1): 40-59.
- Rodrigue, Jean-Paul, and Theo E. Notteboom. 2009. The Terminalization of Supply Chains: Reassessing the Role of Terminals in Port/Hinterland Logistical Relationships. *Maritime Policy & Management* 36 (2): 165-183.
- Saldanha, John P., Dawn M. Russell, and John E. Tyworth. 2006. A Disaggregate Analysis of Ocean Carriers' Transit Time Performance. *Transportation Journal* 45 (2): 39-60.
- Saldanha, John P., John E. Tyworth, Peter F. Swan, and Dawn M. Russell. 2009. Cutting Logistics Costs with Ocean Carrier Selection. *Journal of Business Logistics* 30 (2): 175-195.
- Silver, Ea, Df Pyke, and R Peterson. 1998. *Inventory Management and Production Planning and Scheduling*. 3rd ed. New York: John Wiley & Sons.
- Slack, Brian, Claude Comtois, and Robert Mccalla. 2002. Strategic Alliances in the Container Shipping Industry: A Global Perspective. *Maritime Policy & Management* 29 (1): 65-76.
- Slack, Brian, and Antoine Fremont. 2005. Transformation of Port Terminal Operations: From the Local to the Global. *Transport Reviews* 25 (1): 117-130.
- Song, Dong-Wook, and Photis M. Panayides. 2008. Global Supply Chain and Port/Terminal: Integration and Competitiveness. *Maritime Policy & Management* 35 (1): 73-87.
- Szakonyi, Mark. 2011. "Shipping's New World, Grand Alliances to Merge Asia-Europe Services." *The Journal of Commerce*. Accessed 15 February 2012. <http://www.joc.com/container-lines/new-world-grand-alliances-merge>.
- Tongzon, Jose, Young-Tae Chang, and Sang-Yoon Lee. 2009. How Supply Chain Oriented Is the Port Sector? *International Journal of Production Economics* 122 (1): 21-34.
- Train, Kenneth, and Wesley W. Wilson. 2008. Estimation on Stated-Preference Experiments Constructed from Revealed-Preference Choices. *Transportation Research Part B* 42 (3): 191-203.
- Tyworth, John E., and Amy Zhaohui Zeng. 1998. Estimating the Effects of Carrier Transit-Time Performance on Logistics Cost and Service. *Transportation Research Part A* 32A (2): 89-97.

- Vernimmen, Bert, Wout Dullaert, and Steve Engelen. 2007. Schedule Unreliability in Liner Shipping: Origins and Consequences for the Hinterland Supply Chain. *Maritime Economics & Logistics* 9 (3): 193-213.
- Vidal, Carlos J., and Marc Goetschalckx. 2000. Modeling the Effect of Uncertainties on Global Logistics Systems. *Journal of Business Logistics* 21 (1): 95-120.
- Zamparini, Luca, John Layaa, and Wout Dullaert. 2011. Monetary Values of Freight Transport Quality Attributes: A Sample of Tanzanian Firms. *Journal of Transport Geography* 19 (6): 1222-1234.
- Zhang, Abraham, and George Q. Huang. 2012. Impacts of Business Environment Changes on Global Manufacturing Outsourcing in China. *Supply Chain Management: An International Journal* 17 (2): 138-151.
- Zhang, Abraham, Jasmine Siu Lee Lam, and George Q. Huang. 2013. Port Strategy in the Era of Supply Chain Management: The Case of Hong Kong. *Maritime Policy & Management*: (In press).

Appendix: Approximate transport lead time distributions

Transport lead times in days were used for deriving histograms.

Transport stage 1 (export drayage and port-of-origin dwell)

Service I: Histogram Min = 3, Max = 7, Freq = {1, 2, 4, 5, 3, 2, 1, 1, 1}

Service II: Histogram Min = 2.5, Max = 4.5, Freq = {4, 7, 5, 3, 1} Service III: Histogram Min = 3, Max = 6, Freq = {1, 2, 5, 6, 4, 1, 1}

Daily Maersk: Histogram Min = 0.1, Max = 1.2, Freq = {2, 3, 5, 3, 2, 1, 1, 1, 1, 0, 0, 1}

Transport stage 3 (port-of-destination dwell and import drayage)

Services I ~ III: Histogram Min = 1, Max = 4, Freq = {1, 2, 4, 6, 4, 2, 1}

Daily Maersk: Histogram Min = 0.5, Max = 3, Freq = {3, 4, 6, 4, 2, 1}