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The effect of high fuel costs on liner service configuration in container shipping

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ABSTRACT

For shipping activities, not least container shipping, bunker fuel is a considerable expense. In the last 5 years, bunker prices have risen considerably. An increasing bunker price in container shipping, especially in the short term, is only partially compensated through surcharges and will therefore affect earnings negatively. This paper deals with the impact of increasing bunker costs on the design of liner services on the Europe–Far East trade. The paper assesses how shipping lines have adapted their liner service schedules (in terms of commercial speed, number of vessels deployed per loop, etc.) to deal with increased bunker costs. The paper also includes a cost model to simulate the impact of bunker cost changes on the operational costs of liner services. The cost model demonstrates for a typical North Europe–East Asia loop that the current bunker prices have a significant impact on the costs per TEU even when using large post-panamax vessels. The model also shows shipping lines are reacting quite late to higher bunker costs. The reasons that explain the late adaptation of liner services relate to inertia, transit time concerns, increasing costs associated with fixing schedule integrity problems and fleet management issues.

1. Introduction

Bunker fuel is a considerable expense to shipping lines. In the last 5 years, bunker prices have risen considerably. This paper deals with the impact of increasing bunker costs on the design of liner services on the Europe–Far East trade. The paper assesses how shipping lines have adapted their liner service schedules (in terms of commercial speed, number of vessels deployed per loop, etc.) to deal with increased bunker costs.

The paper is organized as follows. In the first part, we discuss the types of bunkers and the recent price evolution of ship fuels. The second section deals with the environmental pressure on bunkers and the associated use of low sulphur fuels. The two following parts provide a general discussion on how shipping lines are dealing with high bunker costs as well as the relationship between bunker costs and liner service design. The last part of the paper looks at the role of bunker costs in liner service dynamics on one specific trade route: the North Europe–Far East trade. We provide a thorough analysis of the changes in the characteristics of the liner services serving this trade and of the associated cost implications. The paper also introduces a cost model to simulate the impact of bunker cost changes on the operational costs of liner services.

2. The price evolution of bunker fuels

Large amounts of bunker fuel are consumed each year by the world fleet of cargo and commercial vessels as well as the military ones. About 80% of the total bunker fuel relates to heavy fuel oil. Heavy Fuel Oil (HFO) mainly consists of residual refinery streams from the distillation or cracking units in the refineries. The type of HFO is mainly defined by the crude quality and the refinery process. High sulphur crude will result in a high sulphur HFO (Concawe, 1998). Other bunker fuels than the HFO are the marine diesel oil (MDO) and the marine gas oil (MGO). These are distillates from the refinery process with much lower viscosity and lower sulphur content.

Bunker prices constantly fluctuate due to market forces and the cost of crude oil. The bunker market is extremely price sensitive with ships often basing decisions on where to bunker on the relative price of fuel available in respective ports. Bunkering decisions are impacted by relative price premiums arising as a result of different fiscal policies across countries and regions, especially in terms of fuel taxes.

The price difference between crude oil and bunker oil has varied over time. In the last couple of years bunker prices have risen considerably in line with the crude oil price. Table 1 shows the evolution of bunker prices (380 CST grade–CST refers to the unit centistokes and relates to the kinematic viscosity of the residual fuel) at eight selected ports since 2001. Roughly speaking, bunker prices quadrupled between 2001 and the end of 2007, when they

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Table 1
Indicative bunker market prices for 380 CST (average value for the year and peak value in 2007, fourth quarter) at selected ports

	Rotterdam	Genoa	Fujairah	Singapore	Tokyo	Durban	Houston	Long Beach
Indicative bunker market prices for 380 CST (USD per metric ton)								
2001	116	130	128	131	159	135	114	127
2002	133	145	145	148	169	151	134	143
2003	152	165	167	172	193	173	163	163
2004	155	170	177	181	208	180	168	189
2005	234	251	259	264	296	263	250	267
2006	292	312	311	314	345	320	302	319
2007 H1	288	311	321	321	363	322	299	329
2007 Q4	505	516	513	517	565	–	502	505
2007 Q4 vs. 2001	+335%	+297%	+301%	+295%	+255%	–	+340%	+298%
2007 Q4 vs. 2004	+226%	+204%	+190%	+186%	+172%	–	+199%	+167%

Source: Dynaliner.

reached a peak of about 500 USD per metric ton in most of the ports considered. As Table 1 indicates, the price increase was particularly manifest during the last 3 years.

An increase in the bunker oil price has an upward effect on costs. In the tanker market many vessels are on time charter where bunkers are paid by the charterer. Tankers on voyage charter still face considerable bunker price risk. Whether or not these increased costs can be compensated for by higher freight rates depends upon the market at the time. Some commentators suggest that the aggregate bunker price risk for tankers is larger than for liner shipping because of the fact that the ships concerned are generally larger (i.e. they use more fuel for the same distance traveled) and older (i.e. they are less fuel efficient) and there are more of them. Liner companies typically argue they are seriously affected by increasing fuel costs as well.

For liner shipping activities, not least container shipping, ship fuel is a considerable expense. Recent years saw a succession of companies reporting on the effect of the price increases on their accounting bottom lines. Shipowners are using fuel surcharges to recoup some of the increased costs in an attempt to pass the costs on to the customer through variable charges. An increasing bunker price, especially in the short term, is only partially compensated through surcharges to the freight rates via the so-called Bunker Adjustment Factor (BAF) and will therefore affect earnings negatively. All freight rates in container shipping are exclusive of BAF. The BAF may be adjusted in response to fluctuations in bunker oil prices and rate of exchange (USD).

The policy with respect to BAF will change depending upon how a company or liner conference decides to apply the BAF. The carriers cover basic bunker costs, while BAF is only applied to changes above certain trade specific levels. The relationship between BAF and the actual bunker price has often been debated. Cariou and Wolff (2006) investigated whether a causal relationship can be found between the bunker adjustment factor (BAF) and bunker price and between the freight rate and charter rate on the Europe/Far East container trade. Their results suggest that a Granger causality does exist.

A common way of dealing with BAF is to apply a surcharge following Table 2 that will be adjusted on the first day of each month for that month based on the closing bunker price in Rotterdam on the last weekday of the previous month. The BAF scale is based on the bunker price for IFO 380 grade in Rotterdam. The dollar price will be converted to Euros at the closing rate of exchange in London on the same day (last weekday). If the bunker price goes below €140 per ton, the surcharge will be withdrawn.

Liner conferences came up with their own way of dealing with BAF. For example, in November 2007 the member lines of the Far Eastern Freight Conference (FEFC) advised shippers that the BAF applicable for January 2008 will amount to USD 482 per TEU to/from the Mediterranean and West Coast European Region. This equals to more than a third of the freight rate on the dominant westbound leg. The same BAF will apply to the UK, North West Continent, Scandinavia and Baltic Sea Region, plus an additional USD 5 per TEU Low Sulphur Fuel Surcharge. Similarly, the escalating bunker prices during 2007 forced the Trans Atlantic Conference Agreement (TACA) member lines to impose a BAF of no less than USD 607 per TEU (USD 1214 per 40/45 ft. container) for traffic to/from Atlantic/Gulf Coast ports and USD 911 per TEU (USD 1822 per 40/45 ft. container) for traffic to/from Pacific Coast Ports for the period between mid-December 2007 and mid-February 2008.

Table 2
BAF surcharge percentage for bunker price classes

IFO 380 price level (euro per ton)	BAF IFO surcharge (%)	IFO 380 price level (euro per ton)	BAF surcharge (%)
140 (base level)	2.00	216–220	6.50
141–155	2.50	221–230	7.50
156–165	3.00	231–240	8.00
166–180	3.50	241–250	8.50
181–190	4.50	251–255	9.00
191–200	5.00	256–265	9.50
201–205	5.50	266–270	10.50
206–215	6.00	271–280	11.00

Maersk Line started the introduction of a new formula for BAF in early 2008 with the aim of creating more transparency. The formula used in the web-based 'Maersk Line BAF Calculator' builds on factors such as fuel consumption, transit time and imbalances in container flows (press communication Maersk Line, 21 January 2008).

3. Sulphur emission control and its impact on bunker costs

The high fuel costs to shipping lines are not only the result of high costs for heavy fuel. Sulphur emissions from shipping are a major and increasing cause of acid downfall which puts a heavy burden on forests, soil and lakes. Sulphate particles may also create health problems in densely populated areas (ENTEC, 2002; EEA, 2002).

Environmental concerns have resulted in strict emission standards in some parts of the world and more regions are expected to follow such policy. This development is contributing to a gradual shift from heavy fuel to bunkers with a low sulphur content, the so-called low sulphur fuel oil (LSFO). Another solution is to fit cleaning equipment on board such as scrubbers and particle filters.

The policy of the European Commission provides a clear example. The Swedish NGO Secretariat on Acid Rain (2005) estimated that a lowering of the sulphur content of marine heavy fuel oil from the average of about 2.7–0.5% in all European sea areas, would reduce total sulphur dioxide emissions from international shipping around Europe by more than three quarters by 2010, as compared to the emission levels of 2000. Following legislation by the European Commission, the first Sulphur Emission Control Area (SECA) came into force on the 22th November 2006 in the Baltic. The next SECA became effective in August 2007 in the North Sea area (European Commission, DG Environment website). The main effect of this EU legislation is to reduce to 1.5% the maximum sulphur content of marine bunker fuel oil consumed within the SECA. In addition, legislation and environmental considerations are causing consumption of High Sulphur Fuel Oil (HSFO) on land to decline. These changes are significant and will have considerable financial and operating implications for the oil refining and marine industries.

The shift from HSFO to LSFO in parts of the world has implications on ship operating costs. When entering a SECA, the vessel will have to switch to another grade of fuel oil. Price information on the differences between low and high sulphur distillate grades is not readily available. Where both low and high sulphur distillates are available, there is a premium of around USD 10 to 15 per metric ton on the low sulphur fuel (ENTEC, 2002). Premiums seem to be highest in certain EU countries including Greece, Germany and Sweden. The relatively low price premiums in newer EU member countries and the rest of the world are probably due to the availability of low sulphur distillates being incidental as opposed to a result of legislative requirements. The installation of SECAs throughout Europe has made some shipping lines impose a new kind of surcharge, i.e. the 'low sulphur surcharge' that ranges between USD 5 and 10 per TEU.

4. Managing bunker consumption levels

Given the increased bunker costs, shipping lines are challenged to keep a tighter control on bunker consumption. This objective has given incentives for initiatives in the field of (1) the use of cheaper grades of bunker fuel, (2) actions in the field of vessel design and (3) actions with regard to the commercial speed of the fleet and the scale of the vessels.

4.1. Shifts in bunker fuel grades

High fuel costs have made shipping lines look for cheaper alternatives. Cheaper higher-viscosity bunker fuels, such as IFO 420, 500, 600 and 700 grades, are becoming more popular, as the potential savings can be substantial. IFO stands for Intermediate Fuel Oil. The numerical value is the kinematic viscosity of the residual fuel in centistokes (cSt) at 50 °C. IFO 500 is about USD 7-11 cheaper per metric ton than IFO 380, for IFO 700 grade the savings are up to USD 16. The use of high-viscosity bunker fuels, however, is not without complications. The container vessels involved must be able to deal with rougher fuel grades, which often is not the case for older vessels. The higher-viscosity goes with more complex handling issues, but these are more than offset by the savings. Despite an increasing interest in the higher-viscosity grades, however, conventional grades still remain the most popular choice. About 70% of all marine fuel sales (including distillates) in Singapore concerns the conventional IFO 380 grade. In US ports, where higher-viscosity fuels have gained most popularity, the share of IFO 500 remains below 20%.

4.2. Vessel design

To maintain the economic profitability of the vessel, a large focus is nowadays on fuel saving devices in the broadest sense of the word. Vessels lose energy via axial forces. A propeller generates thrust, due to the acceleration of the incoming water. Behind the vessel, the outcoming flow mixes with the environmental flow. Due to turbulence, energy will be lost. There are also frictional losses caused by friction between the water and the propeller blade. And finally a ship encounters rotational losses as the rotation of the blade causes a rotation in the wake too. A number of options are available to improve the efficiency of the propulsion system, depending on the type of propeller and vessel. Propulsion improvements can be realized in the design phase of new vessels or through retrofits to existing vessels. Common improvements relate to propeller polishing and repair of propeller edge damage, a redesign of the current propeller (e.g. a larger propeller diameter in combination with a low rotational speed), rudder adjustments and the conversion of an open propeller to a ducted propeller.

There is a constant search for more fuel efficient vessels through the introduction of more efficient main engines, improved hull forms (e.g. the air lubrication system and improved coating), special devices (e.g. bulbs), more efficient auxiliary machinery, more efficient use of waste energy such as heat, lighter vessels and other innovations in vessel design.

Rational energy use is becoming a hot item in the relation between technical specifications and earnings potential. Veenstra and Ludema (2006) demonstrated that the main variable for the shipowner to buy a ship, or to operate a ship on a certain route is earnings potential. The relation between technical specifications and earnings potential is fairly direct: desired earnings potential influences the design specifications, and the specifications of the finished ship determine the earnings potential.

4.3. Vessel speed and vessel scale

This paper focuses on the third way of controlling bunker consumption, i.e. a sound management of the commercial speed of the vessel. Fig. 1 depicts the relation between service speed and fuel consumption for four types of container vessels and nine different service speeds. This figure indicates that an increase in service speed with just a couple of knots already results in a dramatic increase of fuel consumption. For example, increasing service speed from 23 to 26 knots for an 8000 TEU container vessel increases its fuel consumption by as much as 80 tons per day. These are typical figures that might slightly vary depending on factors such as the draft and trim of the vessel, the hull roughness, fouling, propeller condition, sea state, wind force and direction and currents. With current bunker prices of about USD 450 per ton, this translates into a daily cost increase of USD 36,000. For a 12,500–13,000 TEU container vessel, which will become the workhorse on the Far East–Europe trade route within the not too distant future, the daily cost increase would even amount to USD 51,750 when service speed is increased from 23 to 26 knots.

Table 3 gives an indication of the daily fuel costs at sea (at mid-2006 bunker prices) for three types of container ships and seven different service speeds, as estimated by leading containership classification society Germanischer Lloyd.

As a result of strong growth on the arterial container trade routes in recent years (and nowadays especially on the trade between the Far East and Europe), and in order to anticipate on future volume increases, many shipping lines have embarked upon ambitious expansion plans to upgrade the capacity of their ship fleets. According to AXS-Alphaliner, 3946 cellular containerships were deployed on worldwide trade routes at the beginning 2007, providing a total slot capacity of about 9.6 million TEU (see Table 4). Based on shipping lines' orderbooks as at 01/12/2007, these figures are expected to increase to nearly 5600 ships and

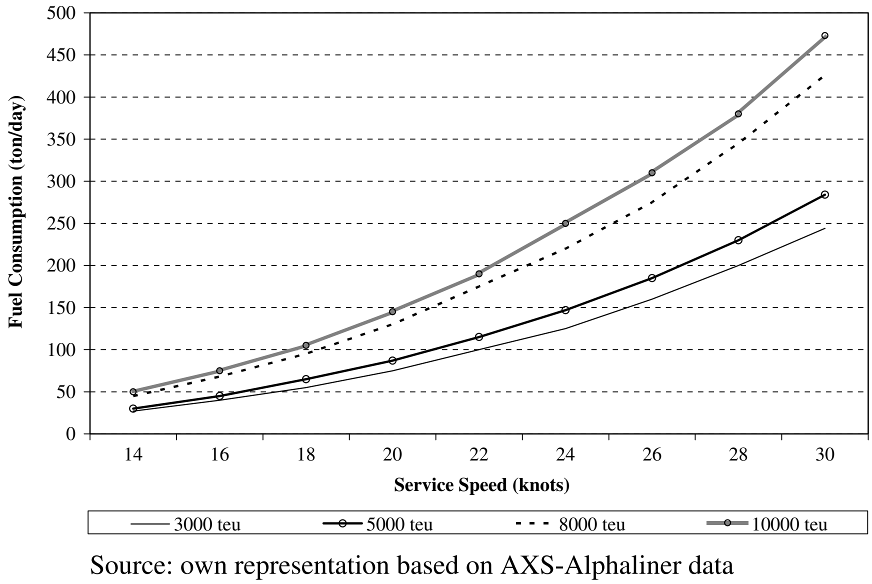

Fig. 1. Daily fuel consumption for four types of container ships at different service speeds.

Table 3
Fuel costs at sea for three types of container vessels and different service speeds (USD per day) at end-July 2006 bunker prices

Speed (kt)	5000 TEU	8000 TEU	12,000 TEU
14	12,200	16,000	20,700
16	16,800	21,600	27,500
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

Source: Germanischer Lloyd.

16.1 million TEU, respectively, by January 2011. This equals a massive increase of nearly 70% in just 4 years time, or 13.7% per year. To put this in perspective, the capacity increase of 6.56 million TEU during 2007–2010 means that a stunning 136,000 TEU-slots will be added to the worldwide cellular fleet every month.

Given the relentless search for cost savings at sea (cf. economies of scale), it is hardly surprising to see that many shipping lines' expansion plans are heavily focused towards large post-panamax containerships. Whereas at the beginning of 2007 the worldwide fleet consisted of 147 vessels of 7500+ TEU (for a total slot capacity of 1.25 million TEU), these figures are expected to increase to 399 ships and 3.74 million TEU by the beginning of 2011. In other words, the capacity provided by 7500+ TEU ships will triple in 4 years time. As Table 4 indicates, the development of the 10,000+ TEU segment is even more stunning. Whereas just two such ships were in service at the beginning of 2007 (with a combined capacity of some 30,000 TEU), their number will have increased to 91 units by the beginning of 2011, providing more than 1 million TEU-slot capacity.

The scale increases in vessel size have resulted in lower bunker costs per slot (commercial speed given). At a commercial speed of 22 knots, the bunker cost per day on a 5000 TEU vessel typically amounts to USD 8.7 per TEU-slot, while the bunker costs for a 12.000 TEU vessel reach only USD 5.4 per TEU-slot or a cost saving of 39% (based on data Table 3). The higher the commercial speed, the greater the cost difference. At a speed of 24 knots, the cost difference rises to 41%, while at 18 knots the cost savings are 34%. Deploying larger vessels thus pays off in bunker costs per slot compared to smaller units, even at high commercial speeds. However, the bunker cost issue becomes more complicated when considering liner services instead of individual vessels, as demonstrated in the next sections.

Table 4
Breakdown of the cellular containership fleet for selected dates

Size range	01/01/2007		01/01/2011[a]		CAGR (TEU capacity) (%)
	No.	TEU	No.	TEU	
>10,000 TEU	2	29,800	91	1094,797	146.2
7500/9999 TEU	145	1223,453	308	2650,218	21.3
5000/7499 TEU	354	2056,329	571	3397,016	13.4
4000/4999 TEU	349	1544,424	605	2668,011	14.6
3000/3999 TEU	282	956,165	391	1333,843	8.7
2000/2999 TEU	650	1635,165	835	2118,080	6.7
1500/1999 TEU	465	784,622	642	1.091,852	8.6
1000/1499 TEU	595	704,570	819	973,327	8.4
500/999 TEU	725	527,983	938	700,120	7.3
100/499 TEU	379	121,243	370	118,516	−0.6
Total	3946	9,583,754	5570	16,145,780	13.9
Average vessel size		2429 TEU		2899 TEU	

Source: AXS-Alphaliner.
[a] Based on orderbook as at 1st December 2007.

5. Bunkers, vessel speed and liner service design

5.1. Liner service design

Schedule design is a strategic planning problem for shipping lines (Fagerholt, 2004). Before an operator can start with the actual design of a regular container service, he will have to assess the market to be served and the distribution of service demand. This requires an analysis of the number and dispersion of final destinations, the density of cargo flows to/from these inland destinations and the existence of trade imbalances. Once the market to be served has been determined, the service planners need to take decisions on three key inter-related elements.

First, the *service frequency*. Carriers will try to have at least a weekly service. In doing so, they make a trade-off between frequency and volume on the trunk lines: smaller unit capacities allow more frequent services and as such meet shippers' demand for lower transit times, while larger units will allow operators to benefit from economies of vessel size.

Second, the *fleet size, vessel size and fleet mix*. The optimal vessel size depends on cargo availability, shippers' needs for transit time or other service elements and the choices made with respect to the other two key variables. As economies of vessel size are more significant on longer distances, the biggest vessels are deployed on the longest routes (see e.g. Cullinane and Khanna, 1999; Lim, 1998), except for the long-haul routes such as Europe-Australasia where smaller volumes urge shipping lines to deploy more modest ships. Carriers have to secure enough vessels to guarantee the desired frequency.

Third, the *number of port calls*. Limiting the number of port calls will shorten round voyage time and increases the number of round trips per year, thereby minimizing the number of vessels required for that specific liner service. However, fewer ports of call mean poorer access to more cargo catchment areas. Adding port calls can generate additional revenue if the additional costs from added calls are more than offset by revenue growth.

Carriers design the networks they find convenient to offer, but at the same time they have to provide the services their customers want in terms of frequency, direct accessibility and transit times. This tension between routing and demand lies at the core of liner service design. Liner service design can also depend on getting agreement from alliance members which can be very time-consuming. The lone operator has an advantage here.

The combination of high bunker costs, larger vessels and stringent demands on the associated liner service networks leads to challenges related to dealing with speed issues in liner service design.

The total time needed for a vessel to do a complete round voyage can be formulated as

$$T_r = \sum_{i=1}^{n} T_{pi} + \frac{D}{V \cdot 24} \tag{1}$$

with T_r is the round voyage time in days; T_{pi} is the total port time in port i in days; n is the number of ports of call on route; D is the distance of the round voyage in nautical miles (nm); V is the vessel speed in knots.

Given a desired service frequency and a desired number of ships deployed on the liner service, the round voyage time should not exceed a certain threshold:

$$T_r \leqslant \frac{S \cdot 7}{F} \tag{2}$$

with F is the frequency of the liner service in number of vessel calls per week in each port of call; S is the number of ships deployed on the liner service.

Combining (1) and (2) gives the minimum required vessel speed needed to operate the liner service at a given frequency, number of port calls, roundtrip distance and number of ships:

$$V = \frac{D}{\left(\frac{S \cdot 7}{F} - \sum_{i=1}^{n} T_{pi}\right).24} \tag{3}$$

Fig. 2 gives an overview of the relationship between roundtrip distance and required vessel speed for a given number of vessels and port calls. The average T_{pi} was set at one day for 10 ports of call and 1.4 days in case of six ports of call (see cost model later in this paper). Fig. 2 represents a best case scenario: it concerns a situation where there are no time buffers in the liner service. In practice, it would be very difficult to run a liner service on such a tight schedule. Hence, a major threat to liner services lies in increased schedule unreliability. Low schedule integrities can have many causes, ranging from weather conditions, delays in the access to ports (pilotage, towage, locks, tides) to port terminal congestion or even security considerations. Notteboom (2006) demonstrated port terminal congestion is currently the main cause of schedule unreliability by far. Vernimmen et al. (2007) also discussed the causes of liner schedule unreliability and analyzed its impacts on various actors throughout the supply chain. Delays in one port cascade throughout the whole liner service and therefore also affect other ports of call. Table 5 depicts the average schedule integrities on trade routes. For example, on the Far East–Europe trade only 44% of the vessels made it according to their schedule. Among the late arrivals, 50% was 1 day late, 20% two days late, roughly 10% three days late and the remaining 20% four or more days late. Maersk Line recorded an average worldwide schedule integrity of 70%. MSC is amongst the poorest performers with only 41%. MSC keeps time buffers relatively low and tries to solve resulting problems via ad hoc changes to the order of port calls and the seemingly random skipping of one or more ports of call during a round voyage. Alternatively, Maersk Line is more strict in respecting the scheduled times and the order of ports of call. Time buffers are sufficiently high to cope with unexpected disruptions.

5.2. Industry's reaction to higher bunker costs

Specialized press reports that shipowners have responded to rising fuel bills with a variety of cost-cutting measures which have included lower vessel speeds and adding new ships to service routes to allow more efficient scheduling (Bunkerworld, November 2006). High bunker prices even broke US Lines as an independent on the transpacific trade and pushed the niche carrier into selling out to partner CMA CGM (Berrill, 2007).

Several shipping lines are adding an extra ship to a number of Asia–Europe loops to deal with high bunker costs and at the same time overcome delays caused by port congestion. The aim is to stop having to sail ships at full speed to catch up lost time and end up burning huge volumes of fuel. Carriers can only slow down by a few knots without damaging ship engines. An increasing number of large container vessels are being ordered with electronically controlled engines that can be operated slower than conventional power units without damage.

In the autumn of 2007 some lines, such as CMA CGM and Maersk Line, decided to reduce service speed and add tonnage. Lloyd's List recently reported that also the New World Alliance lines (APL, HMM and MOL) are to slow down their ships on the Asia–Europe trades in the first quarter of 2008 in order to cut costs by reducing fuel consumption. The consortium plans to deploy nine ships rather than the usual eight in services between Asia and Europe (Porter, 2007). Vessel capacity is being withdrawn from the Pacific as volume growth slows on that trade lane and will

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Table 5
Schedule integrity of liner services on specific trade routes

Trade route	Percentage of on time vessel arrivals[a] (%)
Schedule reliability per trade route – April–September 2006	
Asia/East Coast South America	46
Asia/Europe/Med	44
Asia/Indian Sub/Mideast/Red Sea	62
Asia/Africa	43
Europe/Med/Africa	41
Europe/Med/Aus/New Zealand	31
Europe/Med/Caribbean/Central America	67
Europe/Med/East Coast South America	62
Europe/Med/Indian Sub/Mideast/Red Sea	46
Europe/Med/North Coast South America	44
Europe/Med/West Coast South America	24
North America/Africa	50
North America/Aus	56
North America/Carribbean/Central America	37
North America/East Coast South America	38
North America/Indian Sub	76
Transatlantic	53
Transpacific	63
Total	53

Source: Based on Drewry (2006).
[a] Ship arrives at the port of destination on the scheduled day or on the day immediately before the scheduled day of arrival.

be re-deployed into the Asia–Europe trade where westbound volumes are increasing at annualized rates of around 20%.

Dynaliners reports shipping lines argue that their customers will accept inferior transit times in exchange for improved schedule integrity, resulting from additional buffer allowance. Operating vessels at an economic speed of 20 knots instead of 25 knots would result in a considerable reduction in fuel consumption and an overall operating cost saving. The additional vessels and schedule changes complement other efforts to mitigate fuel costs and reduce the environmental impact of liner services (Dynaliners, 9 November 2007).

6. An application to the Far East–Europe trade

In this section we focus on the Far East–Europe trade route, one of the three arterial East-West container trades where the major share of the fleet of 7000+ TEU vessels is currently being deployed. We first give an overview of the situation as at mid-December 2007 and then compare this with the beginning of 2005. The period early 2005-late 2007 coincides with the period of steep growth in bunker costs. A cost model is introduced in the last sections to simulate the cost impact of vessel speed reduction and the increase in the number of vessels per liner service. The cost model will be applied to a typical liner service on the North Europe–East Asia trade.

6.1. Liner services on the Far East–Europe trade

According to the website of AXS-Alphaliner, some 70 container liner services were offered between ports in the Far East and ports in Europe at mid-December 2007. For the present paper we only focus on the *two-way* services between the Far East and Northern Europe. We thus exclude dedicated Far East-Mediterranean services, Europe-Asia-ANZ services, or Pendulum services. This leaves us with 32 weekly two-way loops. In the period between February 2005 and December 2007 this trade route witnessed a net addition of 5 two-way services.

6.1.1. Number of port calls

The number of port calls (including double calls) on the 32 services in December 2007 ranges between 8 and 20, with an average of 12.63 and a standard deviation of 2.54. On a geographical basis, the port calls are distributed as shown in Fig. 3.

North Europe: The number of port calls ranges between 2 and 6, with an average of 3.66 and standard deviation of 0.87. 15 of the 32 services have 3 ports calls in Northern Europe, while 11 services have 4 port calls. The most frequently visited port is Rotterdam, which is included in 25 of the 32 services. For 10 of these 25 services, the Dutch mainport acts as first port of call for vessels arriving in Northern Europe, further underlying its strong market position for westbound cargoes. Rotterdam is closely followed by Hamburg, which is included in 24 services, however for just 2 of them it acts as first port of call in Northern Europe. Both ports en-

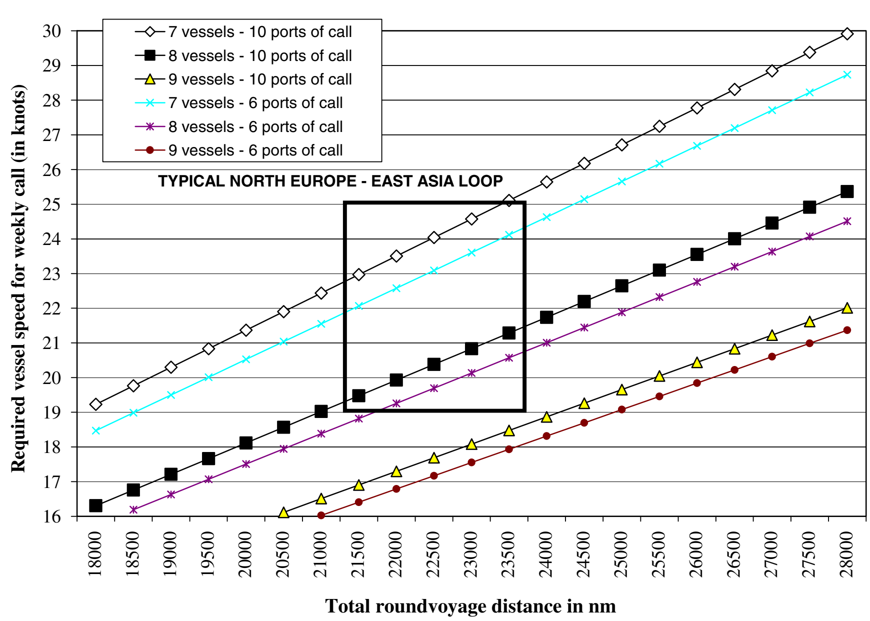

Fig. 2. The relationship between roundtrip distance D and required vessel speed V.

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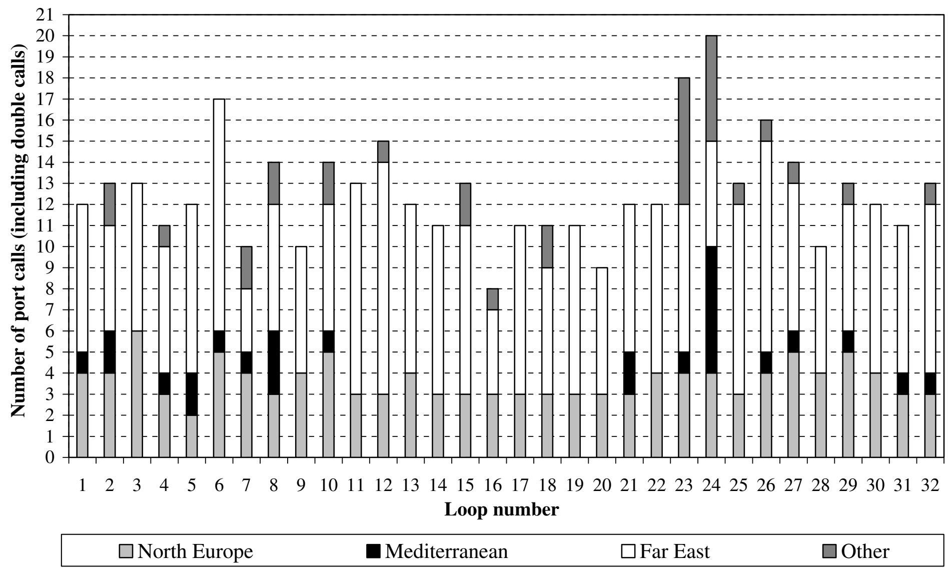


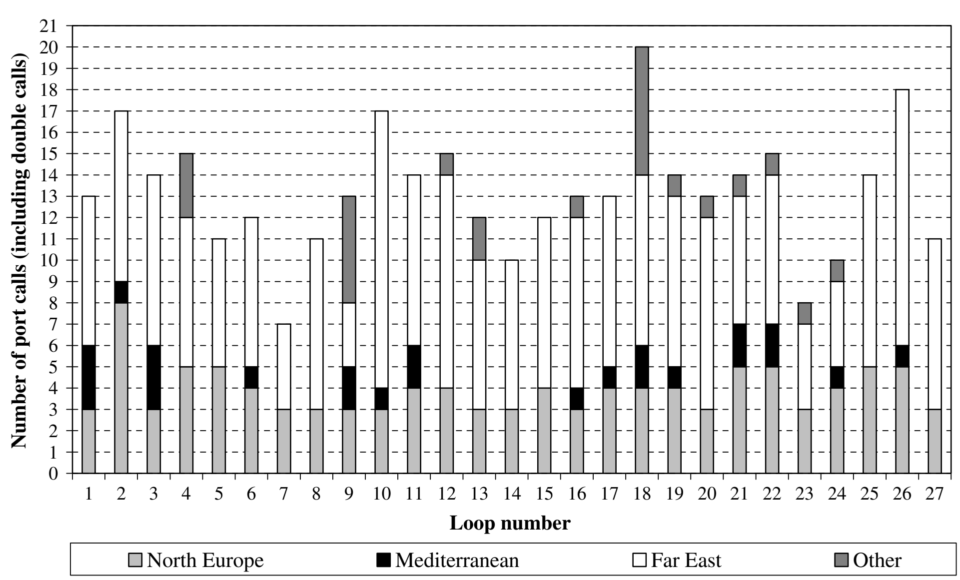
Source: own representation based on AXS-Alphaliner data

Fig. 3. Geographical distribution of port calls on the 32 *two-way* Far East–North Europe container services at mid-December 2007.

joy a strong leading position over Le Havre (included in 13 services, of which 6 as first port of call), Antwerp (11/0), Southampton (10/6), Felixstowe (10/5), Zeebrugge (7/2), Bremerhaven (6/1), Thamesport (4/0), Amsterdam (2/0) and Dunkirk (1/0). The port of Antwerp is *last* port of call on eight of the 32 services, which translates into very competitive eastbound transit times and underlines its strong position for eastbound return cargo. A striking (or perhaps not) fact is that the loop with the biggest vessels (the Maersk Line "AE-7" service, deploying 8 × 15,200 TEU units as from early 2008) calls at just two ports in Northern Europe, in this case Rotterdam and Bremerhaven.

Mediterranean: The number of port calls in this region ranges between 0 and 6, with an average of 0.81 and standard deviation of 1.23. Mediterranean ports which are sometimes called at *en route* from the Far East to Northern Europe (or vice versa) include Algeciras, Barcelona, Beirut, Castellon, Damietta, Genoa, Gioia Tauro, Malaga, Marsaxlokk, Misurata, Port Said, Tangiers, Taranto and Valencia. Quite a number of these ports serve as transhipment hubs.

Far East: The number of port calls ranges between 3 and 11, with an average of 7.19 and standard deviation of 1.82. Hence, as is also apparent from Fig. 3, the 32 *two-way* Far East–North Europe loops include significantly more port calls in the Far East than in Northern Europe. The most frequently visited port in the Far East is the port complex of Shenzhen (comprising Yantian, Shekou and Chiwan) which is included in 25 of the 32 services. Shenzhen is closely followed by Hong Kong (23 services), Singapore (19 services), Shanghai and Ningbo (18 services each). These five ports have a leading position over Port Kelang (11 services), Xiamen (9



Source: own representation based on AXS-Alphaliner data

Fig. 4. Geographical distribution of port calls on the 27 *two-way* Far East–North Europe container services in February 2005.

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services), Busan and Tanjung Pelepas (6 services each), Kobe and Tokyo (4 services each) and Nansha (3 services).

Other (e.g. Near- or Mid-East): the number of port calls ranges between 0 and 6, with an average of 0.97 and standard deviation of 1.43. Ports in this category include Aden, Bandar Abbas, Colombo, Jebel Ali, Jeddah, Khor Fakkan and Salalah.

In February 2005, the number of port calls (including double calls) on the 27 services ranged between 7 and 20, with an average of 13.19 and a standard deviation of 2.88. Hence, these figures are slightly higher than in December 2007. On a geographical basis, the port calls are distributed as shown in Fig. 4. The number of port calls in North Europe ranges between 3 and 8, with an average of 3.93 and standard deviation of 1.14. These figures are slightly higher than in December 2007. The number of port calls in the Mediterranean region ranges between 0 and 3, with an average of 0.89 and standard deviation of 0.97. The number of port calls in the Far East ranges between 3 and 13, with an average of 7.48 and standard deviation of 2.21. These figures are again slightly higher than in December 2007.

6.1.2. Number and size of vessels deployed

In December 2007, the number of vessels deployed on each of the 32 services ranges between 7 and 11 units, with an average of 8.50 and a standard deviation of 0.95. As Fig. 5 indicates, 15 of the 32 Far East–North Europe loops were being run with eight vessels at mid-December 2007. However, as a combined result of the continuously high bunker price levels during 2007 and schedule integrity problems, a number of carriers have decided to add a ninth ship to their service. As a matter of fact, this has been a very popular measure indeed: no less than 11 Far East–North Europe loops were being run with nine vessels at mid-December 2007, whereas at the beginning of 2005 there were only 4 such loops.

There is a significant difference in the size of vessels deployed on the different loops, with the smallest one and biggest one being 2438 TEU and 15,200 TEU, respectively. Taken on a per loop basis, the average vessel size ranges between 2673 TEU and 14,358 TEU, with an average of 7410 TEU. No other trade lane in the world is currently being characterized by such a high average ship size. Moreover, taking into account the current containership orderbook being heavily focused towards 7500+ TEU vessels, the average ship size on the Far East–Europe trade route is bound to increase significantly in the years to come. This will obviously present huge challenges to many players in the industry (not least the terminal operators and port authorities) and will put enormous pressure on hinterland infrastructure.

In February 2005, the number of vessels deployed ranged between seven and 10 units, with an average of 8.12 and a standard deviation of 0.65. These figures are slightly lower than in December 2007. As Fig. 5 indicates, 18 of the 26 services disposing of a full vessel fleet were being run with eight ships, compared to four services with nine ships and one service with 10 ships. Taken on a per loop basis, the average vessel size ranged between 2576 TEU and 8373 TEU, with an average of 5712 TEU.

Table 6 provides an overview of the key indicators of the Far East–North Europe container trade in February 2005 and December 2007. As this table indicates, the number of *two-way* services on this trade route increased, but carriers are focusing on a smaller number of port calls. On the other hand, the average number of vessels per service is increasing and this is being accompanied by a significant increase in average vessel size (+30% over the period considered). As a result, terminal operators have to deal with ever-increasing call sizes, obviously putting severe pressure on marine operations and on the hinterland infrastructure.

6.2. Analyzing a liner service on the North Europe–East Asia trade

6.2.1. Round voyage time, number of vessels and vessel speed

For the purpose of this paper, we have opted for a typical liner service on the North Europe–East Asia trade calling at nine ports in Northeast China, Southeast Asia and North Europe. Total scheduled roundtrip time T_r for this AE1 service of Cosco Container Lines is 55.69 days of which over 9 days of port time (Table 7). The maximum allowable roundtrip time for the liner service at eight vessels deployed ($S = 8$) and a frequency of one call per week ($F = 1$) is 56

Table 6
Key indicators of the Far East–North Europe container trade

	Number of services	Average number of port calls (including double calls)					Avg number of vessels	Avg vessel size (TEU)
		N Eur	Med	Far East	Other	Total		
February 2005	27	3.93	0.89	7.48	0.89	13.19	8.12	5712
December 2007	32	3.66	0.81	7.19	0.97	12.63	8.50	7410

Source: Own calculations based on AXS-Alphaliner data.

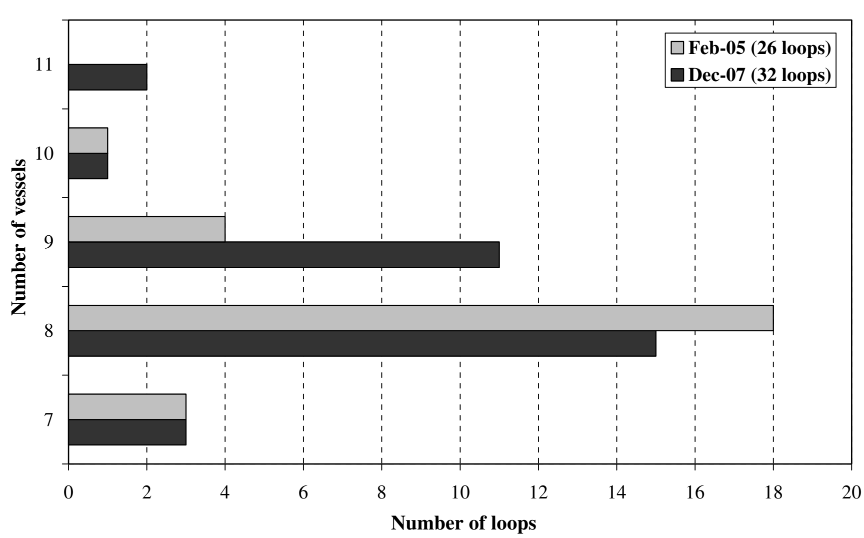

Fig. 5. Vessel deployment on the Far East–North Europe container trade: December 2007 versus February 2005.

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Table 7
Schedule details of the liner service AE1 (based on official schedules)

Port time (days)		
Shanghai		1.02
Dalian		0.56
Qingdao		0.58
Ningbo		0.30
Singapore		0.58
Rotterdam		1.93
Hamburg		2.06
Antwerp		1.17
Singapore		0.54
Hong Kong		0.46
Total port time		9.18
Total roundtrip time (days)	55.69	100.0%
Total port time	9.18	16.5%
Suez Canal	1.42	2.5%
Singapore–Suez	9.54	17.1%
Suez–Singapore	9.45	17.0%
Intra-Asia sailing time	11.33	20.3%
Intra-Europe sailing time	14.77	26.5%
Of which sailing time	45.09	

Source: Authors based on data of Cosco Container Lines.

(see formula (2) outlined above). This implies the schedule at the current speed and current number of vessels is very tight and does not allow for any disruptions or delays.

At a total port time of 9.18 days and eight vessels deployed, the liner service can only be operated comfortably when vessel speed exceeds 22 knots (total sailing time of 44 days, see Table 8), preferably even 23 knots (sailing time of 42 days) to allow for a time buffer of a few days. It is interesting to assess the impact of changes in liner service design.

A *reduction of the number of ports* of call from nine to seven would in theory reduce the total port time by about 2 days, allowing the carrier to stay below the threshold of 56 days of roundtrip time when reducing vessel speed to 20 knots (48 days of sailing time plus 7 days of port time). In practice, however, only a part of the 2 days port time reduction can be realized as more cargo will have to be handled at each port of call, leading to longer terminal activity per call.

An *increase in the number of vessels* has a much higher impact on potential vessel speed reductions. If the shipping line would decide to have nine vessels instead of eight on the loop, then the maximum allowable roundtrip time T_r increases from 56 to 63 days. This would easily allow for a sailing speed of 19 or 20 knots and plenty of time buffers to cope with delays and disruptions. Of course, the cost impact of deploying one more vessel on a loop is more significant than in case of a reduction in the number of port calls. The next section discusses the cost implications of changes in liner service design, with a particular focus on bunker costs.

6.2.2. Cost model for liner service design

In order to have a more detailed insight on this issue, we introduce a cost model consisting of the following cost components:

- Ship costs: these include the vessel operating costs, vessel capital costs, bunker costs and port charges (excluding cargo handling).
- Container costs: these include the cost of supplying containers, container repair and maintenance costs and reefer costs.
- Administrative costs.
- Cargo handling costs including terminal handling costs and cargo claims.

Contrary to Notteboom (2004), the cost model only incorporates maritime-related costs and does not include inland transport costs (pre-haul to port of loading and end-haul from port of discharge), inter-zone repositioning costs or sea-sea transshipment costs (this paper considers a traditional line bundling service). Data were collected on variables such as capital costs, daily running costs, container costs, port dues (sum of towage dues, pilotage dues, traffic control system dues, reporting dues, (un)mooring dues, berth dues and tonnage dues), administrative costs, etc. The bunker consumption at specific vessel speeds and bunker prices were taken from the data introduced earlier in this paper. The cost model builds on earlier conceptual work from Cullinane and Khanna (1999), Baird (2001) and Stopford (1997) which all have included those costs which are a function of ship size. Based on expert information, some general assumptions were made for the North Europe–East Asia trade, irrespective of vessel size: the container mix (57% FEU-slots, 37% TEU-slots and 6% reefer slots) and vessel utilization (95% on the westbound leg and 80% on the eastbound leg). It is assumed that the terminal handling costs per box do not alter with vessel size or route length. The limited fine-tuning and differentiation in the operational cost components are not expected to have a serious impact on the final outcomes.

The total roundtrip distance V is set at 23,200 nm in accordance with the liner service introduced in the previous section. The number of ports (n) equals 10. Three vessel sizes are distinguished: 4000 TEU, 6500 TEU and 9500 TEU. A separate module (including values on average moves per crane per hour, moves per ship call, number of cranes per vessel size and port access time) was used to calculate the average port time for each vessel size and at 10 ports of calls: 0.72 days for a 4000 TEU vessel, 0.94 for a 6500 TEU unit and 1.16 for a vessel of 9500 TEU capacity. At eight ports

Table 8
Total sailing time at different vessel speeds

	Distance (nm)	Sailing time (in days) at speed (in knots)					
		20	21	22	23	24	25
Shanghai–Dalian	576	1.20	1.14	1.09	1.04	1.00	0.96
Dalian–Qingdao	280	0.58	0.56	0.53	0.51	0.49	0.47
Qingdao–Ningbo	512	1.07	1.02	0.97	0.93	0.89	0.85
Ningbo–Singapore	2143	4.46	4.25	4.06	3.88	3.72	3.57
Singapore–Rotterdam	8353	17.40	16.57	15.82	15.13	14.50	13.92
Rotterdam–Hamburg	318	0.66	0.63	0.60	0.58	0.55	0.53
Hamburg–Antwerp	401	0.84	0.80	0.76	0.73	0.70	0.67
Antwerp–Singapore	8343	17.38	16.55	15.80	15.11	14.48	13.91
Singapore–Hong Kong	1435	2.99	2.85	2.72	2.60	2.49	2.39
Hong Kong–Shanghai	875	1.82	1.74	1.66	1.59	1.52	1.46
Total	23236	48.41	46.10	44.01	42.09	40.34	38.73

Note: The sailing distances are based on Dataloy distance tables.

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of call these values would equal to 0.86, 1.13 and 1.4 days, respectively. When the liner service would only include six ports of call the figures would rise to 1.09, 1.46 and 1.82 days, respectively.

Table 9 summarizes the results of the cost model and also includes information on total round voyage time. The bold figures refer to options that are not available to the liner service designer as in these cases the number of vessels is too low to stay below the threshold of the maximum allowable round voyage time (a time buffer of 2 days was included).

The table leads to some important conclusions.

Today, container vessels sailing at 24 knots incur a bunker cost that represents nearly 60% of the total ship costs and up to 40% of the total costs. At a bunker cost of USD 250 per ton these figures were 44% and 28%, respectively. These high percentages are exceptional. Buxton (1985) reported that in the early eighties fuel costs typically made up 50% of ship costs excluding capital charges and cargo handling and 14% of the overall company costs (at a time when the bunker price for IFO180 amounted to around USD 180–190 per ton). The results in Table 9 are also in line with various press reports on the issue. Dynamar recently reported bunker costs now account for two-thirds of voyage operating costs (Dynaliners, 9 November 2007).

Second, the results reveal that the deployment of vessels of 9500 TEU sailing at lower speeds requires 9 vessels, while only 8 smaller ships are needed to guarantee the same weekly call. Scale enlargements in vessels size thus lead to an increasing pressure on shipping lines to increase the number of vessels per loop or to reduce the number of port calls. This is especially felt when high bunker costs urge shipping lines to reduce vessel speed. This conclusion partly explains the observations in Fig. 5 presented earlier in this paper. The deployment of large ships can only be justified, therefore, in tandem with the taking of a decision on their deployment (i.e. frequency and, in particular, the number of port calls). The interdependency between increasing container ship size and the load centre concept has been discussed previously by Cullinane and Khanna (1999) and later elaborated upon in Cullinane and Khanna (2000).

Third, increasing bunker costs put the economies of scale in vessel size in a new perspective. In 2005, when bunker costs amounted to some USD 250 per ton, the cost for transporting a TEU on the North Europe–East Asia trade with a 4000 TEU ship sailing at 22 knots was about the same as the cost for using a 9500 TEU vessel to do the same today. However, this observation does not question the validity of investing in larger scale tonnage. It is the opportunity cost of not making the investment in larger tonnage that is the most salient aspect of the scale issue within this context of rising fuel prices over time.

Figs. 6 and 7 provide more detail on the relationship between bunker price per ton and total liner service costs and costs per TEU transported respectively for the liner service we introduced in Section 6.2.1. The figures reveal that it is interesting for a shipping line to shift from eight to nine vessels and reduce speed from 23 to 20 knots when the fuel price is higher than around USD 150 per ton. Changes in the number of ports of call have only a small impact on the total costs per TEU transported and do not change the USD 150 per ton mark. The carrier can even save costs by increasing the number of port calls from 8 to 10 while increasing the number of vessels from eight to nine as long as the bunker price is higher than USD 200 per ton. At the present fuel rates of around USD 450 per ton, the cost gap has become very significant. As demonstrated in Fig. 5, quite a number of shipping lines have adapted their service schedules accordingly. Still, it remains remarkable why shipping lines have not reduced vessel speed earlier in combination with an increase in the number of vessels. Based on a selected set of interviews with shipping line representatives on the issue, we argue that there are five reasons for the 'late' reaction of carriers.

Table 9
Cost comparison for different vessel sizes, bunker costs and vessel speed-cost in USD per TEU transported (port-to-port basis)

Cost per TEU transported (USD)	Vessel size and speed								
	4000 TEU			6500 TEU			9500 TEU		
	20 kn	22 kn	24 kn	20 kn	22 kn	24 kn	20 kn	22 kn	24 kn
Bunker cost = USD 450 per ton, round trip = 23,200 nm, 10 ports of call									
Ship costs excluding bunker costs	285	266	251	254	237	224	218	204	193
Bunker costs	252	305	352	208	252	293	190	226	273
Container costs	89	89	89	89	89	89	89	89	89
Administrative costs	33	33	33	28	28	28	28	28	28
Cargo handling costs	142	142	142	142	142	142	142	142	142
Total	801	836	867	721	748	776	667	689	724
% bunker costs in ship costs	47%	53%	58%	45%	52%	57%	47%	53%	59%
% bunker costs in total costs	31%	37%	41%	29%	34%	38%	28%	33%	38%
Total round voyage time (days)	55.6	51.2	47.5	57.7	53.3	49.7	59.9	55.5	51.8
Maximum allowable round voyage time									
at 7 vessels	**49.0**	**49.0**	49.0	**49.0**	**49.0**	**49.0**	**49.0**	**49.0**	**49.0**
at 8 vessels	56.0	56.0	56.0	**56.0**	56.0	56.0	**56.0**	56.0	56.0
at 9 vessels	63.0	63.0	63.0	63.0	63.0	63.0	63.0	63.0	63.0
Bunker cost = USD 250 per ton, round trip = 23,200 nm, 10 ports of call									
Ship costs excluding Bunker costs	285	266	251	254	237	224	218	204	193
Bunker costs	140	169	196	116	140	163	105	126	151
Container costs	89	89	89	89	89	89	89	89	89
Administrative costs	33	33	33	28	28	28	28	28	28
Cargo handling costs	142	142	142	142	142	142	142	142	142
Total	689	700	711	628	636	645	582	589	603
% bunker costs in ship costs	33%	39%	44%	31%	37%	42%	33%	38%	44%
% bunker costs in total costs	20%	24%	28%	18%	22%	25%	18%	21%	25%

The bold values are not a feasible option.
Source: Cost model results – Notteboom.

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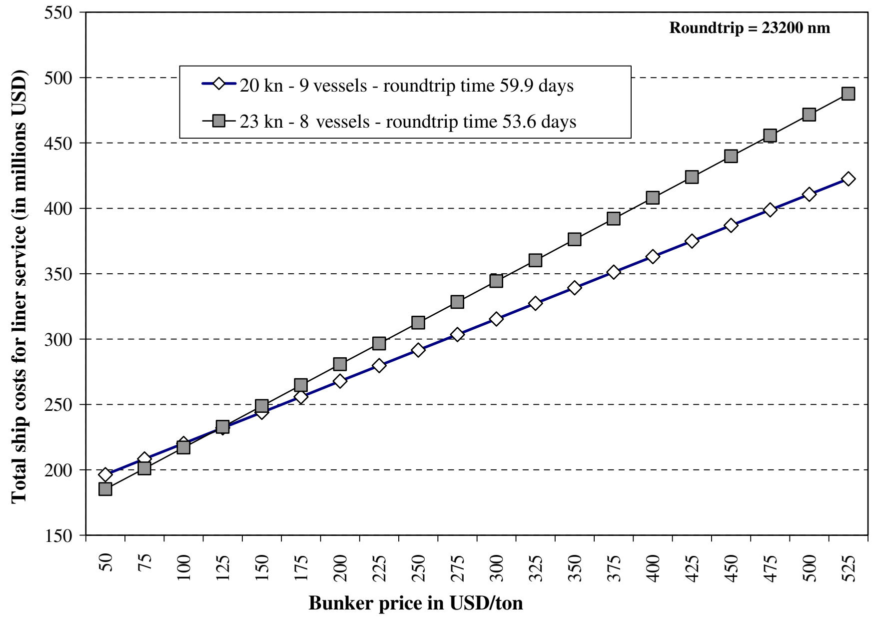

Fig. 6. Total liner service costs as a function of the bunker price. Roundtrip of 23,200 nm and 10 ports of call.

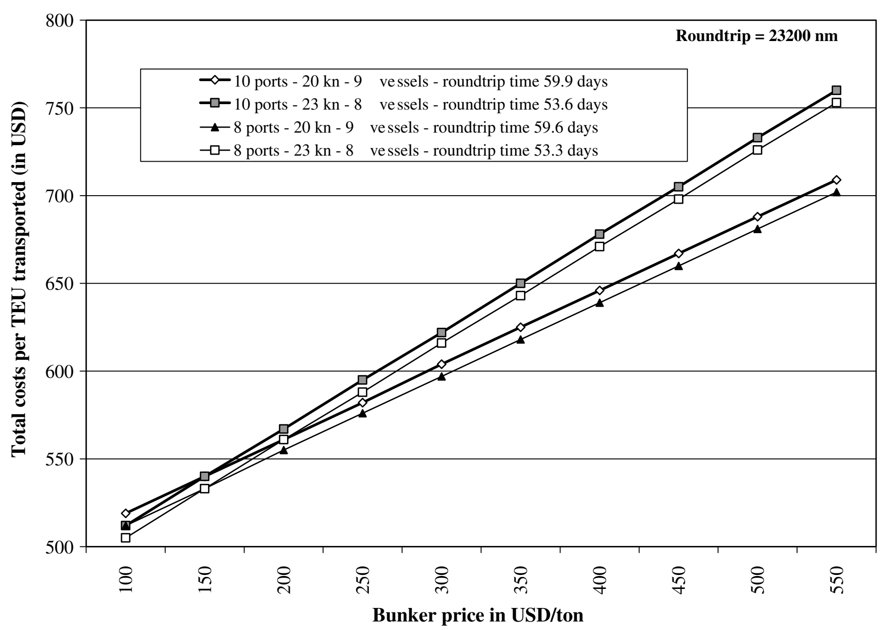

Fig. 7. Total costs per TEU transported as a function of the bunker price. Roundtrip of 23,200 nm.

First, shipping lines suffer to some extent from a certain level of inertia in adapting their liner services. They have waited till the cost gap became very significant, before taking action. Figs. 6 and 7 reveal that for this specific case the shipping line could have already saved on ship costs in 2005 when the bunker rice was reaching USD 250 per ton. However, at that time the cost gap was still not very significant. Most carriers interviewed stated that they did not expect the fuel price to remain so high or become even more elevated. In 2007, shipping lines were continuously facing very high bunker costs and they have come to realize that high bunker costs have become a fact of life requiring structural adaptations to their service schedules.

Second, shipping lines are very eager to offer short transit times to their customers, but slower steaming evidently has a negative impact on transit times. For example, Table 9 revealed that a reduction in vessel speed from 24 to 20 km increases total roundtrip time with about 8 days. The resulting one-way transit time from Asia to Europe is likely to increase by 3–4 days, depending on the positions of the port of loading and discharge in the port of call sequence. So, shipping lines are constantly making a trade-off between high vessel speed/short transit times and the potential cost savings of sailing slower. In the last couple of years it has become apparent that short transit times and schedule integrity are under pressure due to delays in ports and overall port con-

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gestion. Time savings gained through an elevated vessel speed are often counterbalanced by time losses in ports and along maritime access routes and straits (see Section 5.1 outlined above). This has made more and more shippers value a high schedule reliability at a slightly longer transit time instead of a scheduled short transit time with a low reliability.

Third, customers are generally not keen on having too many changes in liner service schedules. Regular and reliable services give customers the ability to pre-book slots in advance to match with, for example, their production schedules that are ultimately dependent on their orders and supplies. Thus, to maintain an appropriate market presence and to ensure customer allegiance, liner shipping companies need stability in their schedules. There is a certain reluctance, therefore, to change them in response to short term changes in circumstances. Changes in fuel prices need time before they emerge as long-term trends when liner operators may then feel inclined to react. In any case, inertia will be inevitable because existing (current) schedules and advanced bookings of containers on future ship calls made on the basis of this advertised schedule will restrict the agility of container shipping companies to change the average speed of the vessels deployed on the route. Moreover, alliances take time to change any aspect of service delivery.

Fourth, shipping lines interviewed stated they have come to realize that schedule unreliability is causing additional bunker costs. Hence, when a container vessel is subjected to delays at one side of the trade (e.g. North Europe) then shipping lines used to do everything to get the vessel back on schedule by the time it arrives at the first port of call on the other side of the trade (e.g. East Asia). The associated costs tend to be very high as illustrated in the following example. Assume that a vessel of 9500 TEU capacity operating on the AE1 loop of Cosco incurs a delay of 2 days in European ports. At a vessel speed of 22 knots the total roundtrip time T_r amounts to 55.5 days, just below the threshold of the maximum allowable round voyage time of 56 days (assume eight vessels deployed on loop). In order to guarantee a reliable schedule, Cosco will have to increase vessel speed on the leg between Antwerp (last port of call in Europe) and Singapore (first port of call in Asia). At 22 knots it would take the vessel 15.8 days to reach Singapore. Due to the delay incurred in Europe, the container ship will have to sail to Singapore in 13.8 days in order to get back on schedule, implying an average speed of 25 knots. At 22 knots the bunker costs on the route Antwerp-Singapore amount to USD 1.35 million (190 ton per day at USD 450 per ton), while at 25 knots the bunker costs reach USD 1.71 million (275 ton per day at USD 450 per ton) or an additional USD 357,000 (an extra USD 38 per available TEU-slot). Solving schedule reliability problems thus comes at a high price. Increasing the number of vessels to nine allows for significant time buffers in liner service operations, allowing shipping lines to cope with potential delays at a lower cost.

Fifth, the traffic boom in China and other Asian countries has urged shipping lines to introduce new liner services and a new generation of large container vessels. Shipping lines typically allocate new vessel units to new liner services or replace the smaller ships in an existing loop (upgrading). Shipping lines typically strive for a well-balanced fleet mix within the individual loops they operate. Large size differences among the vessels operating within the same schedule decrease operational homogeneity. There are however operational and financial barriers to a shockwave increase in vessel size, so the fleet mix might not always be so homogeneous. Upgrading the vessel size on a specific route can take several years and demands huge phased investments. Increasing the number of vessels from eight to nine on a loop further complicates fleet management, both in terms of the required replacement investments on existing loops and the vessel capacity required to introduce a new liner service. For a long time, shipping lines have been reluctant to dedicate new capacity to add vessels to existing loops as the demand for replacement investments was very high in a market where vessel capacity was very tight. A shortage of tonnage over recent years prior to the current building boom limited liner options to quickly add tonnage to each service. In the last year or so, the capacity situation on the Europe – Far East trade eased somewhat due to newbuildings entering the market. This market situation combined with the high bunker costs and port congestion problems made shipping lines allocate a significant share of the total new capacity for the purpose of increasing the number of vessels on a loop. On top of this, the increase of the number of vessels per loop on the Europe-Asia trade has also helped absorb ships that could have been left idle after being withdrawn from the Pacific trades.

7. Conclusions

Bunker costs constitute a considerable expense to container shipping lines. In the last 3 years, bunker prices have risen considerably. An increasing bunker price in container shipping, especially in the short term, is only partially compensated through surcharges to the freight rates and will therefore affect earnings negatively. On top of this, there is new legislation on the use of more expensive low sulphur fuels. Shipping lines are challenged to keep a tighter control on bunker consumption. They can do so by using cheaper grades of bunker fuel, by aiming for fuel efficient vessel designs and by adapting their liner service design in terms of vessel speed, vessel size and number of vessels per loop. This paper focused on the last element by analyzing the impact of increased bunker costs on the design of liner services on the Europe–Far East trade. It was demonstrated that the number of two-way services on the Far East–North Europe container trade increased in the period between February 2005 and December 2007, but carriers are focusing on a smaller number of port calls. On the other hand, the average number of vessels per service is increasing and this is being accompanied by a significant increase in average vessel size (+30% over the period considered). Moreover, shipowners have responded to high fuel bills with a variety of cost-cutting measures which have included lower vessel speeds and adding new ships to service routes to allow more efficient scheduling. Adding an extra ship also helps to overcome delays caused by port congestion. The aim is to stop having to sail ships at full speed to catch up lost time and end up burning large volumes of fuel.

The causality between changes in liner service design and bunker costs is somewhat blurred by schedule integrity concerns. We argue that high bunker costs are giving shipping lines a strong operational incentive to lower vessel speed and increase the time buffers in the liner services by adding an additional vessel. High bunker costs are thus helping to partly solve schedule integrity issues as they trigger a trend to increased time buffers, at least for the liner service we have analyzed (a liner service where roundtrip time is tight for a given number of ports of call and vessels). The commercial implication of such action is that customers have to be willing to accept inferior transit times in exchange for improved schedule integrity, resulting from additional buffer allowance.

The cost model introduced in the last part of the paper demonstrated (at least for one specific liner service) that the current bunker prices have a significant impact on the costs per TEU even when using large post-panamax units. The model also showed shipping lines are reacting quite late to the higher bunker costs. Based on a series of interviews, we have identified several reasons that explain the late adaptation of liner services: inertia, transit time concerns, increasing costs associated with fixing schedule integrity problems and fleet management issues.

Up to now, the relationship between fuel consumption and liner service design has not drawn a lot of attention in academic circles, while it is a major concern to ship managers and service planners. Further research is needed to analyze the full impact of fuel costs on wider liner service networks and to relate this to the schedule integrity issue. Hence, this paper only discussed individual line bundling services on the Europe–Asia trade calling at several ports at either side of the trade route. The results and conclusions might depend upon the specific route considered. This paper provided no sensitivity analysis with respect to changes in the assumption on route distance. The present study can be extended by analyzing the role of fuel costs at different roundtrip distances. A further extension also consists in assessing the impact of bunker prices and schedule integrity issues on the competitiveness of hub-and-spoke configurations on specific trade relations.

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