Some key variables affecting liner shipping costs

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Abstract

The liner shipping sector is one of the most dynamic segments of ocean transportation, and one that is also inextricably connected to the port and terminal sector and to land transport modes due to its intermodal nature. This paper takes stock at some published work on liner shipping costs, and tries to identify key variables that affect these costs and how each of these variables impacts these costs. The impacts of ship size, speed, port time, route distance and bunker costs are presented and discussed.

1. Introduction

It is fair to say that the overall literature on liner shipping is immense, covering a very broad array of topics, ranging from the economics of the liner market to engineering aspects of containership design, from liner network design to legal-regulatory aspects of the market, from ship routing and scheduling to safety and security, and from containership air emissions to port and terminal management, to name just a few. Clearly the liner shipping sector is one of the most dynamic segments of ocean transportation, and one that is also inextricably connected to the port and terminal sector and to land transport modes due to its intermodal nature.

This paper takes a look at liner shipping costs, as examined in some selected key references that study this important attribute of the overall liner shipping operation. With the design size of containerships already reaching the 15,000 TEU scale, and with sizes above 20,000 TEU already being planned by major container lines, economies of scale are likely to be an important cost factor in the future. Indeed, economies of scale suggest that a larger ship is cheaper per ton to build, and running costs per ton also fall. At the end, the operating costs per container-mile decrease (reduction of unit costs of container carriage). However, other cost components, especially related to time spent in ports, may have the opposite trend, and thus it is not clear that the total cost function is a monotonically decreasing function of ship size. Besides, other factors such as speed, network design and the way a fleet is utilized may be just as important as size. It should be clarified that due to paper size limitations, the review of literature connected with operations research - optimization methods in liner shipping, is outside the scope of this paper, even though there is an obvious ‘operational’ connection to the topic presented here.

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The rest of this paper is organized as follows. Section 2 starts with the topic of economies of size. Section 3 examines the effect of port time, speed, and route distance and Section 4 investigates the impact of bunker costs. Section 5 presents the conclusions of the paper.

2. Economies of size

One can begin by citing the seminal work of Gilman (1999) and of Jansson and Shneerson (1982), among others, on the topic of economies of size in container transport. According to Lim (1994), the "economies of size" are measured by comparing unit earnings and unit costs for different vessel sizes. Also, the distortions of the hypothesis that "larger is better" by certain other factors were examined, such as the vessel's purchase price, the average freight rate level, average voyage lengths for the trade, achieved load factors, and accounting procedures.

The Charter Base (CB) and Hire Base (HB) were used, the CB as a revenue index and the HB as an expense index. The CB is the contribution margin (or marginal income) of a vessel per day for a specific voyage. The contribution margin is equal to revenue minus variable expenses. CB is calculated by subtracting variable operation costs from freight revenues and dividing the difference by operation days. In this paper a further calculation of CB per TEU was made for selected vessels.

CB: Freight Revenue - Variable Operation Costs (cargo related expenses + navigation expenses) = Contribution Margin / Operation Days

HB reflects the daily costs allocated to the fully-manned ship whether in revenue-earning operation or not. The expense items considered are crew and vessel expenses, and various overheads such as administrative, facility and equipment, and various non-operation expenses borne by the shipowner. The HB may be calculated by dividing total fixed costs (running costs + capital costs + overhead) by operation days.

HB = [Fixed Costs (i.e. ship expenses + crew expenses + insurance + depreciation + overhead)] / Operation Days

HB per TEU was used. If CB is higher than HB, the operation will be profitable. The examined hypothesis is that HB/TEU decreases with increments of vessel size.

The operational performance of different size ocean container ships on different routes was examined for a certain year. Details of freight revenue, cargo expenses, navigation expenses, ship expenses, overhead were collected. Proportions of various expenses to total expenses were also estimated. The considered cost structure of container shipping is represented in Table 1.

HB/TEU data did not support the hypothesis that unit costs necessarily decrease with increments of vessel size. This implied that there are other components affecting unit costs and that ship size is only one possible explanatory factor. Another conclusion reached was that it is desirable to use container ships of uniform size on particular routes.

Another indicator used was the cost per TEU per mile carried. The cost per TEU-mile can be calculated by dividing total costs by total amount of transport service produced during a specific period of time. The total amount of transport service was calculated by multiplying total navigated miles by the total number of containers a ship carried for a specific period of time. No empirical evidence suggested that TEU-mile cost decreases as ship size increases.

The final conclusion was that the economies of container ship voyages depend on many factors unrelated to size; for instance, on route characteristics, accounting practices, prevailing level of freight rates, load factors, operation days and the shipbuilding market. Especially, the unit cost of a vessel may be strongly biased by the ship's purchase price. Scale economies in the bulk trades, especially the tanker trades, is much more dramatic and evident than in the container trades.

Table 1: Cost structure of container shipping (adapted from Lim, 1994)

Variable costs	
Cargo-related expenses	Cargo expenses: CFS charges (stuffing, stripping), measuring/weighing, tallying, cargo inspection, customs examination, documentation, non-containerized / overheight / overwidth / dangerous cargo surcharge, reefer cargo expenses (pre-trip inspection, pre-cooling, monitoring, storage), etc.
	Terminal Handling Charges (THS): loading / unloading / receiving / delivery (lift onto chassis for empty despatch, lift off from chassis for receiving outbound load, load into vessel from stacking area for outbound cargo and discharge from vessel into stacking area, lift onto chassis for delivery, lift off from chassis for empty return for outbound cargo), shifting (from cell to cell, unload on the terminal and reload on the same vessel), transshipment (unload on the terminal and reload on another vessel on the same terminal), storage of full and empty container, stevedorers or equipments stand-by charge, overtime surcharge, etc.
	Haulages: railroad charge, rail ramp fee, inland depot charge, inland transportation, local drayage, port equalization, port shuttle, feeder charge, etc
	One-way short-term lease for container, chassis and trailer.
Navigation expenses	Port charges: pilotage, towage, dockage, wharfage, harbour / tonnage / light / buoy / anchorage dues, mooring / unmooring and running lines, customs/quarantine fee, watchman / agency / cana1 fee, etc.
	Bunker expenses: fuel and marine diesel oil.
Fixed costs (running costs and capital costs)	
	Crew expenses: wages, overtime, pensions, accident / sickness insurance, traveling / repatriation, provisions, victualling and cabin stores, etc.
	Vessel expenses: stores / spares, lubricants, maintenance / minor repair, annual survey, fresh water, communication charge, etc. (c) Insurance: hull / machinery, war risks, freight / demurrage

	defence, P&I, other marine risks, etc.
	Depreciations: ship, container, chassis, trailer and other container related equipment, terminal property and equipment, etc.
	Amortization for long-term terminal, container, chassis and trailer leaseholds and leaseholds improvements, etc.
Overhead	
	Administrative expenses: compensation of officers and directors, salaries and wages of employees, fringe benefits, rental expenses, office expenses, communication expenses, dues and subscription, travel expenses, advertising, entertainment and solicitation, legal fees, taxes, etc.
	Non-operating revenues: interest income, dividend income, revenue from non-shipping operations, foreign exchange gains, income from affiliated companies, etc.
	Non-operating expenses: interest expenses, foreign exchange losses, donations and contributions, miscellaneous losses, etc.

However, as for example Graham (1994) notes, one should be careful to omit revenue and cost items which are not a function of ship size from a study designed to look at the economic effects on service profitability of variations in ship size. For example, not all land-side costs should be included and neither all kind of administrative costs.

Davies (1983) notes that in liner shipping the short-run may be defined as the period of time within which it is not possible to vary either the size of the fleet operated by a company or the frequency of service. Once a schedule has been agreed upon, cost items such as fuel, crew wages, maintenance and repair (regarded as variable costs in other industries) become fixed, which cannot be avoided in the short-run planning horizon. Variable costs, that change directly with the magnitude of cargo carried, are associated with handling, loading and stowing cargo.

Stopford (2004) identifies six components of liner service costs: service schedule, ship costs, port charges, container operations, container costs, and administration. Indicative figures for these costs and for several ship sizes are provided in Table 2 that follows.

Regarding the service schedule (1st component), key decisions concern the service frequency, the number of port calls and the size of the ships to be used. The ship cost (2nd component) is usually expressed in terms of unit slot cost (e.g. cost of transport for 1 TEU per day). Operating, capital and fuel costs are important elements. Since bunker costs are substantially higher for container ships than bulk vessels, due to their higher speed, fuel consumption is a particularly important variable. Economies of scale have an impact on unit slot cost. Port charges (3rd component) are beyond the control of the shipowner and vary around the world. As they depend on the ship's tonnage, economies of scale are again important. Container operations (4th component) costs depend on the mix of container types, container turnaround time and empty containers that must be repositioned inter-regionally. Container costs (5th component) include daily cost, maintenance, repair, and handling, among other. Administration costs (5th component) are related to management, logistics, financial, and commercial aspects of the business.

Table 2: Building blocks of liner costs according to Stopford (2004)

	Ship size (TEU)			
	1,200	2,600	4,000	6,500
1. Service schedule	1,200	2,600	4,000	6,500
Distance of round trip	8,500	8,500	8,500	8,500
Service frequency	weekly	weekly	weekly	weekly
Portcalls on round voyage	7	7	7	7
Average operating speed (knots)	19	19	19	19
Days/portcall	1.35	1.35	1.35	1.35
Days at sea	18.6	18.6	18.6	18.6
Days in port	9.5	9.5	9.5	9.5
Total voyage time	28.1	28.1	28.1	28.1
Outward capacity utilization (%)	80%	80%	80%	80%
Return capacity utilization (%)	90%	90%	90%	90%
Containers shipped outward (TEU)	960	2,080	3,200	5,200
Containers shipped back (TEU)	1,080	2,340	3,600	5,850
Annual transport capacity (TEU)	106,371	230,471	354,571	576,179
2. Ship Costs				
Operating Costs ($/day)	5,500	6,650	8,550	9,500
Capital value $mill	25	42	58	80
Depreciation period (years)	20	20	20	20
Interest rate (% pa)	8%	8%	8%	8%
Capital cost/$ day	8,904	14,959	20,658	28,493
Fuel consumption (tons/day)	50	65	80	95
Bunker price $/ton (average)	110	110	110	110
Bunker cost ($/day)	5,500	7,150	8,800	10,450
Unit cost per TEU ($/day)	16.6	11.1	9.5	7.5
3. Port charges (excluding cargo handling)				
Port Cost/$ TEU	18	11	9	7
Port Cost/$ call	22,000	29,000	35,000	43,000
4. Container operations				
Twenty ft containers (% ship capacity)	37%	37%	37%	37%
Number of units loaded	444	962	1,480	2,405
Forty ft containers (% ship capacity)	57%	57%	57%	57%
Number of units loaded	342	741	1,140	1,853
Refrigerated containers (% ship capacity load)	6%	6%	6%	6%
Number of units loaded	72	156	240	390
Number of units on full vessel	858	1,859	2,860	4,648
Container turnaround time (days/voyage)	75	75	75	75
Containers repositioned empty (%)	10%	10%	10%	10%
5. Container costs				
Container costs ($/TEU/day) 20 ft	0.9	0.9	0.9	0.9
40 ft	1.4	1.4	1.4	1.4
20 ft reefer	8.5	8.5	8.5	8.5
Maintenance and repair ($/box/voyage)	75.0	75.0	75.0	75.0
Terminal costs for container handling ($/lift)	200.0	200.0	200.0	200.0
Refrigeration cost for reefer containers ($/TEU)	150.0	150.0	150.0	150.0
Trans-shipment ($/TEU)	225.0	225.0	225.0	225.0
Inland intermodal transport cost ($/TEU)	150.0	150.0	150.0	150.0
Interzone Re-positioning ($/TEU)	150.0	150.0	150.0	150.0
Cargo Claims ($/box/voyage)	25	25	25	25
6. Administration Costs				
Administrative productivity (TEU/employee)	400	550	700	950
Number of employees required	266	419	507	607
Cost/employee $ per annum	40,000	40,000	40,000	40,000
Administration cost ($/TEU)	100	73	57	42

Source: Various, but particularly Drewry Shipping Consultants (1996)

In Table 3, Stopford (2004) combined the above cost information with revenue to determine the financial performance of a liner service. Cost information are summarized into four sections, the fixed cost of the ships (section 1), the cost of the containers (section 2), the administration costs (section 3) and the cargo handling and onward transport cost (section 4). From these items, the voyage cost per TEU is calculated in section 5. The voyage revenue (section 6) is then added to calculate the voyage profit or loss (section 7).

Table 3: Liner service cash flows example according to Stopford (2004)

	Ship size (TEU)			
	1,200	*2,600*	*4,000*	*6,500*
	$ 000s	$ 000s	$ 000s	$ 000s
1. Fixed costs of the ship				
Operating costs	154	187	240	267
Capital costs	250	420	580	800
Bunkers	103	133	164	195
Ports	154	203	245	301
Total	**661**	**943**	**1,229**	**1,563**
Per cent total voyage costs	42%	33%	30%	26%
2. Costs of the containers				
Cost of supplying containers	125	272	418	679
Container maintenance & repair	90	195	300	488
Total	**215**	**467**	**718**	**1,167**
Per cent total voyage costs	14%	16%	18%	19%
3. Administration cost				
Administrative cost allocated to voyage	**120**	**189**	**229**	**274**
	8%	7%	6%	4%
4. Cargo handling and onward transport				
Terminal costs for container handling	172	372	572	930
Refrigeration cost for reefer containers	11	23	36	59
Inland intermodal transport cost	306	663	1,020	1,658
Interzone re-positioning	36	78	120	195
Cargo claims	51	111	170	276
Total	**575**	**1,247**	**1,918**	**3,117**
Per cent total voyage costs	37%	44%	47%	51%
5. Total voyage cost				
Total cost	**1,572**	**2,846**	**3,696**	**5,570**
Cost per TEU Outward Leg ($)	819	684	640	588
Cost per TEU Return Leg ($)	728	608	569	523
Average cost/TEU[1]	771	644	602	554
Per cent reduction in cost/TEU by using bigger ship		−16%	−6%	−8%
6. Total voyage revenue ($ 000s)				
Freight rate per TEU Outward Leg	820	820	820	820
Freight rate per TEU Return Leg	750	750	750	750
Revenue outward leg[1]	787	1,706	2,624	4,264
Revenue return leg[1]	810	1,755	2,700	4,388
Total revenue	**1,597**	**3,461**	**5,324**	**8,652**
7. Profit (loss) ($ 000s)				
Voyage profit (loss)	25	615	1,230	2,531
Per cent	2%	18%	23%	29%

As different size ships are considered, it is shown that the effects of economies of scale are especially important for the fixed costs of the ship shown in section 1, where the total cost of the 6,500 TEU ship is almost three times the cost of the 1,200 ship, but the cargo volume is almost six times as great. As the size of ship increases, the fixed cost component falls from 42% to 26%. The other cost components do not especially benefit from economies of scale. In section 5, the average cost per TEU falls from USD771 for the 1,200 TEU vessel to USD554 for the 6,500 TEU vessel. In the end, and at the considered cargo levels, the 1,200 TEU vessel makes a profit of USD25,000, a 2% return, while the 6,500 TEU vessel makes a profit of USD2.53 million, a return of 29%. This example outlines the rationale behind the liner companies ordering bigger ships.

3. The effect of port time, speed, and route distance

Cullinane and Khanna (2000) develop a model which quantifies the economies of scale in operating large containerships. They note, as widely recognized, that costs at sea per tonne or per TEU will decrease as ship size increases. However, the overall efficiency of a ship depends ultimately on the total time the ship takes to complete a voyage, because the time spent in port is unavoidable in the sense that cargo will need to be loaded and unloaded. So, there is a trade-off between the positive returns earned at sea and the negative returns accruing while in port (during the handling operation). Their model attempts to quantify this trade-off by considering only those costs which are a function of ship size.

Given the size of the investment, the treatment of capital cost in the model is also important. To ensure that economies of scale relative to the building cost are introduced to their analysis, a submodel of newbuilding prices is used, which is functionally dependent on ship size. Newbuilding contract prices are converted into an annual capital charge by applying a capital recovery factor which assumes that the life of the vessel is 20 years, the interest rate is 10% and the residual value is 0.

The time taken on a voyage and the distance travelled on that voyage are the two causal factors which have a strong effect on costs. Their approach involves mainly three submodels, which yield the following outputs: the Daily Fixed Cost per TEU; the Cost per TEU-Mile; the Total Shipping Cost per TEU (see Figure 1).

The first submodel analyses cost variability in response to changes in time to derive a standard cost per TEU per unit time. This is an input to the second submodel which assesses cost variability in relation to distance travelled. The third submodel combines the output from both the previous submodels yielding a composite picture of the total cost of a voyage.

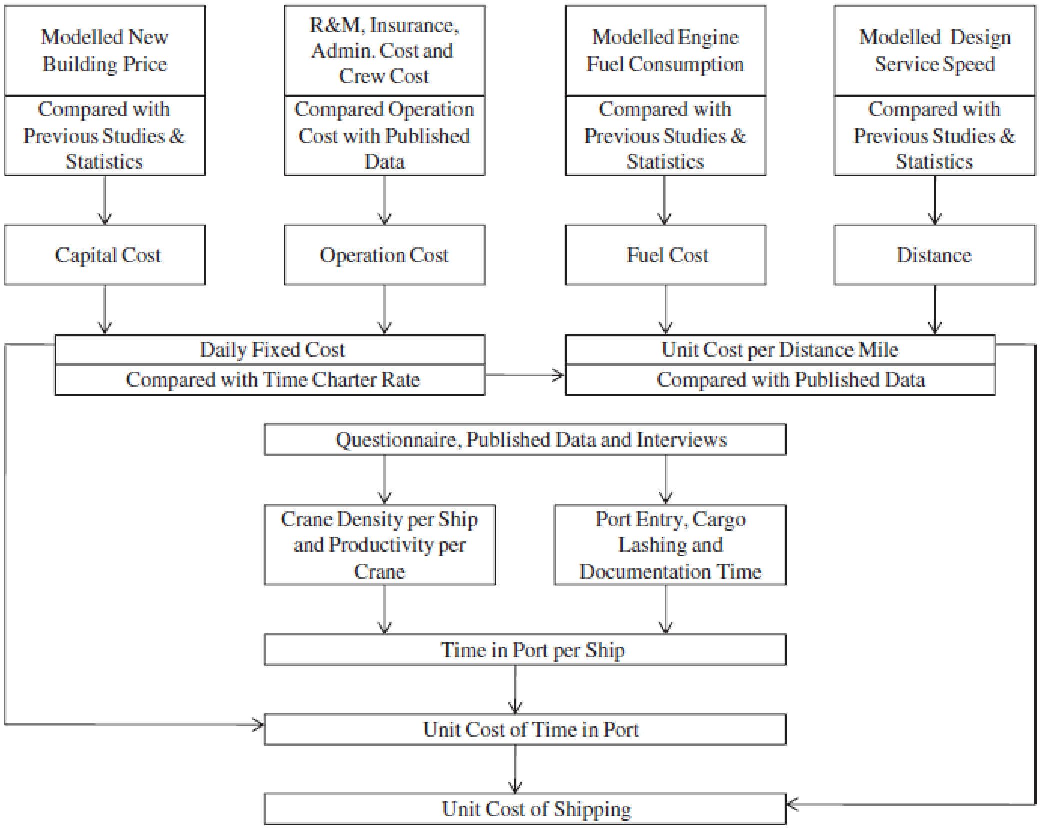


Figure 1: Representation of the aggregate model (as adapted in Ng and Kee, 2008)

Cost per TEU-Mile and ship speeds for different ship sizes are shown in Figure 2 which illustrates that, besides being more economical, larger ships are also faster and capable, therefore, of providing a better service and better utilisation of assets.

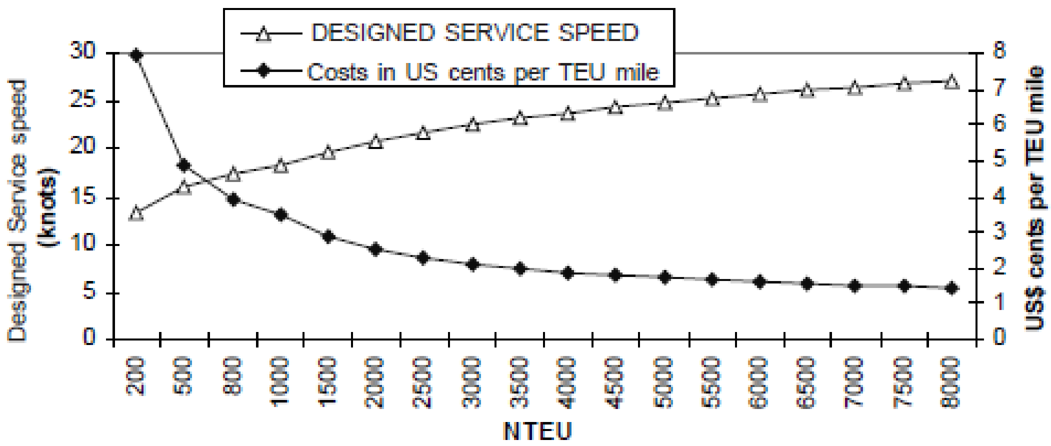


Figure 2: Containership size vs. design speed and cost per TEU-mile (Cullinane and Khanna, 2000)

The cost of time in port expressed in USD per TEU per voyage is given in Figure 3. This cost has been calculated as the product of the estimated number of days spent in port during each of the voyage scenarios and the daily cost. Port time depends on total cargo exchange, crane density, average crane productivity, non-productive time in port, working time in port, etc. The daily cost of ship's time varies with factors such as capital cost, repairs and maintenance, insurance, crew, diesel oil consumption and price, etc.

Dramatic improvements in port productivity are related to a significant improvement in average crane productivity in recent years. Also, as ship size increases, there is an increase in the average number of cranes employed on the ship.

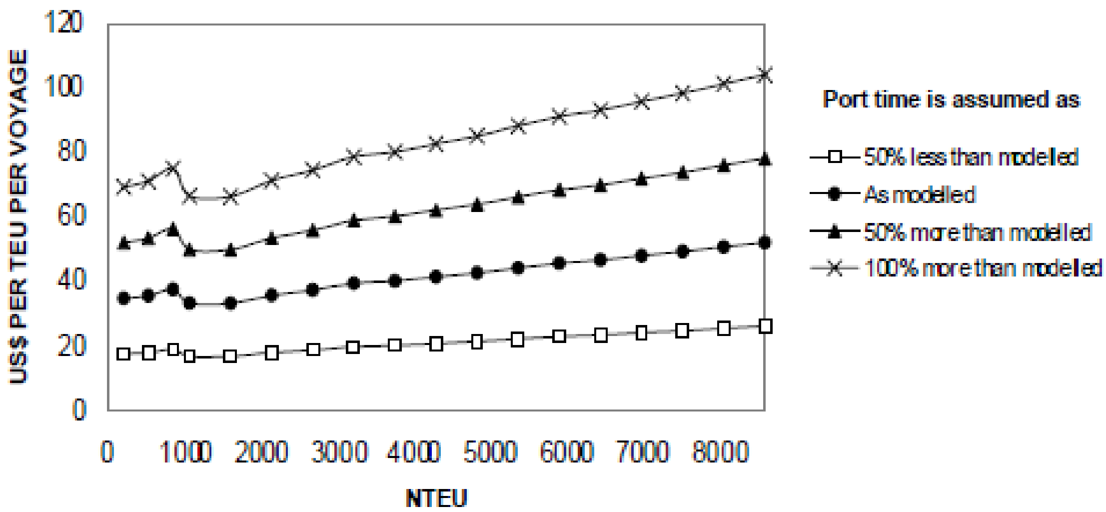


Figure 3: Containership cost of time in port per voyage (Cullinane and Khanna, 2000)

Three main East-West routes were considered, i.e. Europe-Far East, trans-Pacific and trans-Atlantic. The resulting Total Shipping Cost per TEU for each of these three sample routes are shown in Figure 4. For all three sample route lengths, the results suggest that economies of ship size are enjoyed until about 8000 TEU. Also, for these three voyage lengths, the diseconomies of ship size in port are outweighed by economies of size at sea.

Results also suggested that the benefits from scale economies in ship size decline as route lengths shorten. Figure 4 shows that the shorter the route length, the flatter is the line graph showing Total Shipping Cost per TEU. This implies that the economies of ship size are of greater benefit on longer routes.

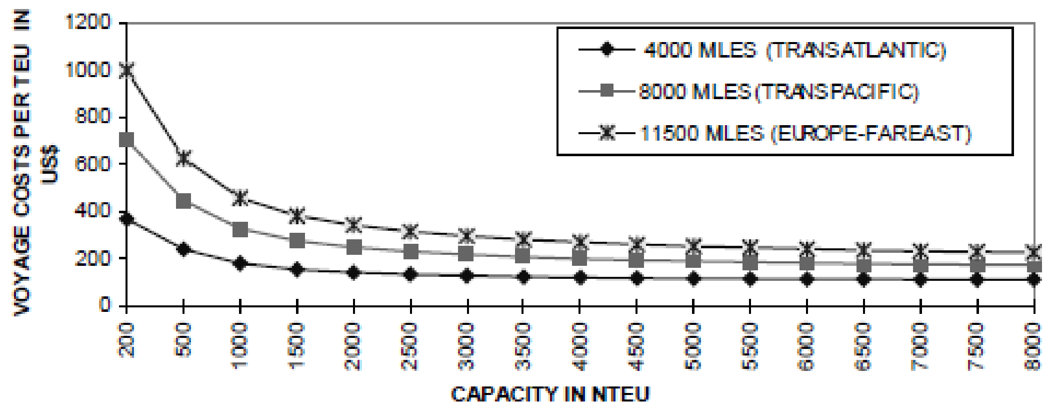


Figure 4: Distance comparison of total shipping costs per TEU (Cullinane and Khanna, 2000)

Figure 5 graphically illustrates the decline in positive returns to scale as ship size and route length increase. The deployment of large containerships is likely to depend most crucially on voyage distance.

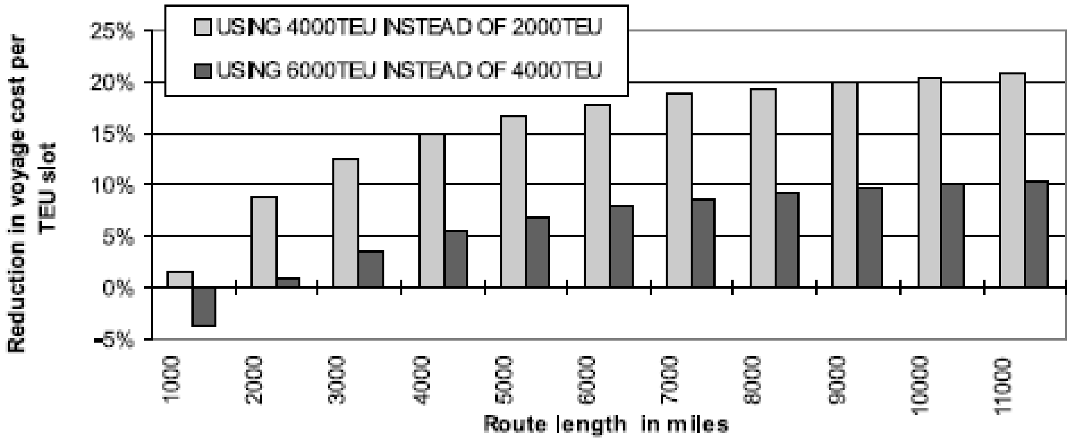


Figure 5: Comparison of economies of scale and route length (Cullinane and Khanna, 2000)

Ting and Tzeng (2003) consider the cost items and categories that are useful in liner shipping route planning. Voyage fixed costs and freight variable costs need to be estimated, in order to conduct a profitability analysis

Voyage fixed costs are constant regardless of the volume of freight. These can be analysed on one round-trip voyage basis, and include four major items: vessel costs, port charges, bunker costs and equipment costs.

Vessel costs (of a carriers' own vessels) include: (1) Crew costs: crew wages, provisions, health insurance and other crew-related expenses; (2) Vessel maintenance costs: inspections, repairs, extraordinary dry-dockings and classification survey costs; (3) Insurance costs: hull insurance and P&I; (4) Vessel depreciation costs; (5) Fleet management fees[2].

Bunker costs include marine diesel oil (A oil), heavy fuel oil (C oil), cylinder oil, engine system oil and lubrication oil consumption.

Port charges include wharfage, tonnage dues, light dues, pilotage, towage, mooring / unmooring fees, oil pollution levy, quarantine fees, electricity/utility charge, port state inspection fees, garbage removal charge and government duties. Additionally, if the vessels pass a canal (e.g. Suez canal, Panama canal), canal transit tolls and booking fees must be included.

Equipment costs include hire, depreciation, insurance, maintenance and repair expenses for containers and chassis.

Estimations for the above described four major cost items of a voyage fixed cost are provided in Table 4 for a Trans-Atlantic service route.

Table 4: Fixed cost items for Trans-Atlantic service route (5 charter-in containerships are deployed to the route and provide a weekly service) (Ting and Tzeng, 2003)

1. Fleet costs		**2. Container and chassis costs**	
Fleet : 5 vessels (2,000 TEU)		Hire	111,810
		Depreciation	54,493
Vessel hire (USD/day)	12,000	Insurance	3,361
Voyage days	35	Repair and maintenance	49,105
Total fleet cost per voyage	**420,000**	Container and chassis cost per voyage	**218,769**
3. Bunker costs		**4. Port charge**	
Distance (nautical miles)	11,730	Charleston	11,500
Average speed (knots)	17	Miami	11,500
Total steaming time (h)	643	Houston	11,500
Total steaming time (days)	26.8	New Orleans	11,500
A oil		Antwerp	30,000
A oil price (USD/ton)	143	Felixstowe	30,000
A oil consumption (ton/day)	3.5	Bremerhaven	38,000
A oil consumption cost (USD)	17,518	Rotterdam	30,000
C oil		Lisbon	25,000
C oil price (USD/ton)	102	Total port charge per voyage	**199,000**
C oil consumption (ton/day)	74		
C oil consumption cost	202,085		
Total bunker cost per voyage	**219,603**		
Total fix cost per voyage (1+2+3+4)		**1,057,372 USD**	

2 The above five cost items are included in carriers' own vessel daily costs. When vessels are chartered in on time-charter instead, vessel daily costs include daily hire, P&I and management fees.

On the other hand, variable costs are directly related to the volume of freight, and include six major items: (1) feeder costs; (2) trailer/railway costs; (3) container handling costs; (4) tally costs; (5) container management and repositioning costs; (6) terminal stowage costs.

Estimations for these variable cost items are provided in Table 5 for the same Trans-Atlantic service route.

Table 5: Variable cost items for Trans-Atlantic service route (due to transshipment pattern differences between east-bound and west-bound voyages, variable costs are estimated separately for each direction) (Ting and Tzeng, 2003)

Variable cost items	East bound	West bound
Feeder costs	130	75
Trailer/railway costs	186	185
Container handling costs	160	198
Tally costs	78	82
Container management and repositioning costs	48	55
Terminal stowage costs	22	22
Another costs	4	4
Unit variable costs (USD/TEU)	628	621

Song et al. (2005) present a model that attempts to reproduce the overall incomes, costs, and container movement patterns for the global container-shipping network. They collected and adjusted realistic data in order to model the global patterns for the year 2002.

A cost model was adopted to calculate the vessel running cost. This included the bunker cost, auxiliary cost, lube cost, capital cost, crew cost, insurance cost, maintenance cost, box cost and port cost. The port cost was composed of three parts: stevedoring (lifting) charge, fixed charge per vessel call, and vessel capacity-related due. The stevedoring charge was assumed to be $100 per lift, the fixed fee $1500 per vessel call and $1 per TEU for vessel capacity related due. A load factor of 0.8 was assumed for all services. The shipping cost (freight rate) that a shipping line charged a shipper was assumed to be the vessel running cost multiplied by a profit margin ratio. A ratio of 2.0 was used, equivalent to an overhead cost of 100%. This factor was utilized to reflect the missing costs such as management costs.

The results on incomes, costs and container movement patterns (including fleet capacity, total box moves carried, total transhipment moves, port fixed cost, port lifting cost, total running cost, total income and utilization) for the ten largest shipping lines by vessel fleet capacity are given in Table 6. The port fixed cost is the cost that the shipping line must pay to ports even if there are no containers lifted. The port lifting cost is proportional to the total number of lifts (loads/unloads) at ports. Total cost represents the vessel running cost including port dues.

Although the proposed results of this paper are subject to the assumptions and limitations of the model, as well as the use of sufficiently realistic input data, they are provided here as approximate values representing cost aspects of the container shipping market.

Table 6: Incomes, costs and movement patterns for the top ten shipping lines by capacity (Song et al., 2005)

Shipping line	Fleet capacity ('000TEU)	Total moves ('000TEU)	Tran. moves ('000TEU)	Port fixed cost ($m)	Port lifting cost ($m)	Total cost ($m)	Total income ($m)	Utilization (%)
Maersk Sealand	652	17779	6923	112	3556	6709	11563	80
P&ON	382	7334	2968	58	1467	3218	5491	74
MSC	380	8403	2403	74	1681	3470	5791	70
APL	251	7318	2240	40	1464	2709	4578	72
Cosco	219	4098	233	39	820	1889	2720	57
Evergreen	216	3740	1101	28	748	1663	2691	57
Hanjin	208	4024	422	24	805	1795	3103	73
CMA CGM	176	3393	868	28	679	1460	2371	60
NYK Line	174	3806	1112	25	761	1592	2741	73
K Line	172	4112	972	27	822	1664	2836	73

Some additional estimations of container ships' annual operating costs are provided in Table 7.

Table 7: Estimations of container ships annual operating costs (Youroukos, 2007)

Fixed Annual Operating Cost

Estimated Container ship Cost (US$ Price Levels)							
Twenty-Foot Equivalent Units (TEUs)	600	1.000	1.200	1.400	1.600	2.000	2.200
Deadweight Tonnage (DWT; metric tonnes)	9.000	14.000	17.000	20.000	23.000	28.000	31.000
Fixed Annual Operating Cost(s)							
Crew Cost(s)	631.745	658.859	685.972	713.086	740.199	767.313	807.983
Lubes & Stores	251.566	270.393	289.220	308.047	326.873	345.700	373.941
Maintenance & Repair	532.123	544.439	556.756	569.073	581.390	593.706	612.182
Insurance	254.363	268.449	282.534	296.619	310.704	324.790	345.917
Administration	106.081	106.654	107.227	107.801	108.374	108.948	109.808
Total Fixed Annual Operating Cost(s)	**1.775.878**	**1.848.794**	**1.921.709**	**1.994.626**	**2.067.540**	**2.140.457**	**2.249.831**

Estimated Container ship Cost (US$ Price Levels)							
Twenty-Foot Equivalent Units (TEUs)	2.500	2.800	3.000	3.500	4.000	4.800	6.000
Deadweight Tonnage (DWT; metric tonnes)	35.000	39.000	42.000	49.000	55.000	66.000	82.000
Fixed Annual Operating Cost(s)							
Crew Cost(s)	835.096	924.157	953.884	1.028.061	1.072.591	1.102.278	1.473.363
Lubes & Stores	392.767	403.033	406.455	415.009	420.142	423.564	466.337
Maintenance & Repair	624.498	658.634	670.013	698.459	715.527	726.905	896.138
Insurance	360.003	419.386	439.181	488.667	518.358	538.153	785.584
Administration	110.381	115.506	117.214	121.485	124.047	125.756	147.109
Total Fixed Annual Operating Cost(s)	**2.322.745**	**2.520.716**	**2.586.747**	**2.751.681**	**2.850.665**	**2.916.656**	**3.768.531**

Ng and Kee (2008) place their focus on liner feeder routes, which are also important components in a hub-and-spoke system, while studies on optimal ship size mainly refer to major inter-continental trunk liner routes. They make a literature review investigating different cost components of a containership, in order to assess economies of scale (which suggest that a lower unit cost can be achieved when more units of a particular good/service are produced on a bigger scale with less input costs).

Figure 6 displays the cost structure of a hypothetical ship with a breakdown in variable and fixed costs, depending on whether an item varies with operational level. Generally speaking, in the short run[3], capital and repayment costs, tax, depreciation, labour and insurance are considered fixed, while repairs, maintenance and daily running costs are partly fixed. Administrative expenses have both fixed and variable components. Additional crew expenses are classified as partially variable while bunkers, stevedoring, port and canal dues are classified as variable costs. The operational (running) cost would comprise repairs and maintenance, daily running cost, administrative cost and additional crew expenses.

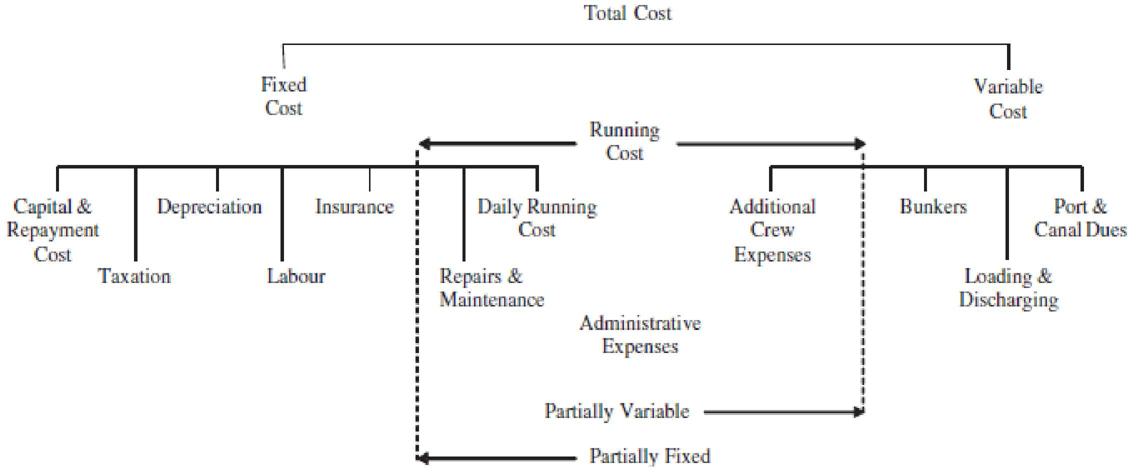


Figure 6: Cost structure of a hypothetical ship (McConville, 1999)

Coming to the specific case of a containership, Table 8 shows a possible cost structure with a breakdown in operation and fixed costs.

Table 8: Cost structure of a containership (Branch, 1998)

Operation cost	Fixed fost
Direct cost	Administration
• Terminals	Stores
• Transport	Bunker fuel
• Packing/unpacking	Dry docking/maintenance
• Others	Insurance
Ship cost	Crewing
Port charges and dues	Depreciation
Containers	
• Provision	
• Imbalance/repositioning	
Administration	

[3] In the long term, fixed costs would become variable costs and so the limitation of timeframe is crucial in determining what costs should be categorized as fixed costs within a certain time period.

While bigger ships may enjoy lower unit cost, they need to tackle additional challenges. Big ships are often harder to handle due to more demanding requests, in terms of both money and time, related to navigation channels along rivers/canals, port's berthing draught, port access channels and cargo handling facilities. The major weakness of only analysing ship-related cost is that such an approach neglects the potential externalities imposed on other components of the logistical supply chain. Figure 7 displays a U-shaped average cost curve, when both ship and non-ship-related costs are included in the analysis.

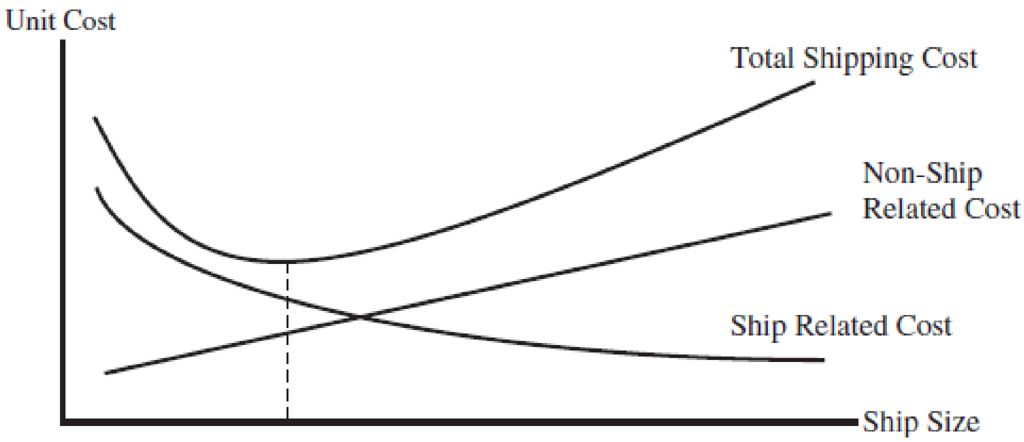


Figure 7: The total shipping cost including ship and non-ship related components (adapted from Kendall, 1972)

4. The effect of bunker costs

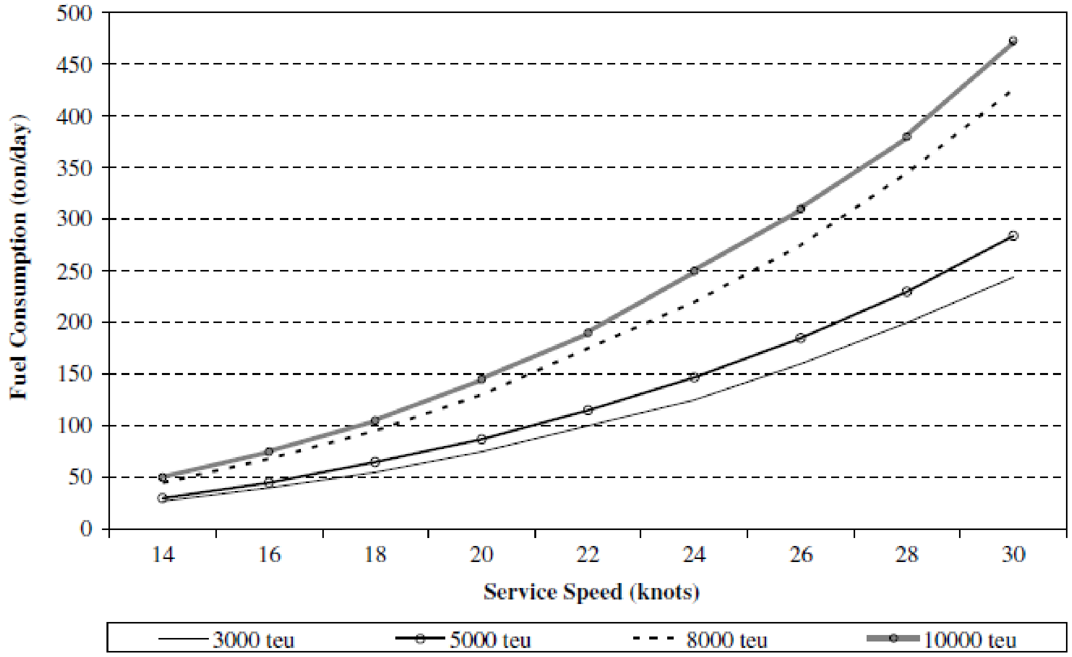
Notteboom and Vernimmen (2008) examine the bunker fuel cost, which is a considerable expense in liner shipping. Their paper assesses how shipping lines have adapted their liner service schedules (in terms of commercial speed, number of vessels deployed per loop, etc.) to deal with increased bunker costs. Bunker prices constantly fluctuate due to market forces and the cost of crude oil. Increasing bunker prices generally affect earnings negatively.

Shipping lines have attempted to pass the costs on to the customer through variable charges. For example, 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). 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) and it is applied to changes above certain trade specific levels. The policy with respect to BAF changes depending upon how a company or liner conference decides to apply the BAF.

About 80% of the total bunker fuel relates to heavy fuel oil. High sulphur crude will result in a high sulphur heavy fuel oil HFO, referred to as HSFO. Sulphur emission controls and environmental considerations encourage a gradual shift from heavy fuel to bunkers with a low sulphur content, the so-called low sulphur fuel oil (LSFO)[4]. Other bunker fuels than the HFO are the marine diesel oil (MDO) and the marine gas oil (MGO).

The shift from HSFO to LSFO has implications on ship operating costs. 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. This 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.

Figure 8 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. With 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, the daily cost increase would even amount to USD 51,750 when service speed is increased from 23 to 26 knots.



Source: own representation based on AXS-Alphaliner data

Figure 8: Daily fuel consumption for four types of container ships at different service speeds (Notteboom and Vernimmen, 2008)

Table 9 gives an indication of the daily fuel costs at sea. The scale increases in vessel size have resulted in lower bunker costs per slot. 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%.

[4] See, for instance, latest amendment of Annex VI of MARPOL, adopted at IMO' MEPC 58 (London, October 2008), stipulating drastic reductions in the sulphur content of marine fuels.

Table 9: Fuel costs at sea for three types of container vessels and different service speeds (USD per day) at end-July 2006 bunker prices (Notteboom and Vernimmen, 2008)

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.

Moreover, 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. The global drive to reduce ship air emissions, which are directly proportional to the amount of fuel burned, also contributes to this goal (more on this later).

For the purpose of their paper, the authors considered a typical liner service on the North Europe–East Asia trade. They used a cost model to simulate the impact of bunker cost changes on the operational costs of liner services. Their cost model consisted of the following cost components (incorporates maritime-related costs and not inland transport costs):

- Ship costs (including the vessel operating costs, vessel capital costs, bunker costs and port charges - excluding cargo handling),
- Container costs (including 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).

Table 10 summarizes the results of the cost model. For example, 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 450 per ton). At a bunker cost of USD 250 per ton these figures were 44% and 28%, respectively.

Figures 9 and 10 provide more details on the relationship between bunker price per ton and total liner service costs and costs per TEU transported respectively for the considered liner service. The figures suggest for example 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.

Table 10: Cost comparison for different vessel sizes, bunker costs and vessel speed-cost in USD per TEU transported (port-to-port basis) (Notteboom and Vernimmen, 2008)

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.

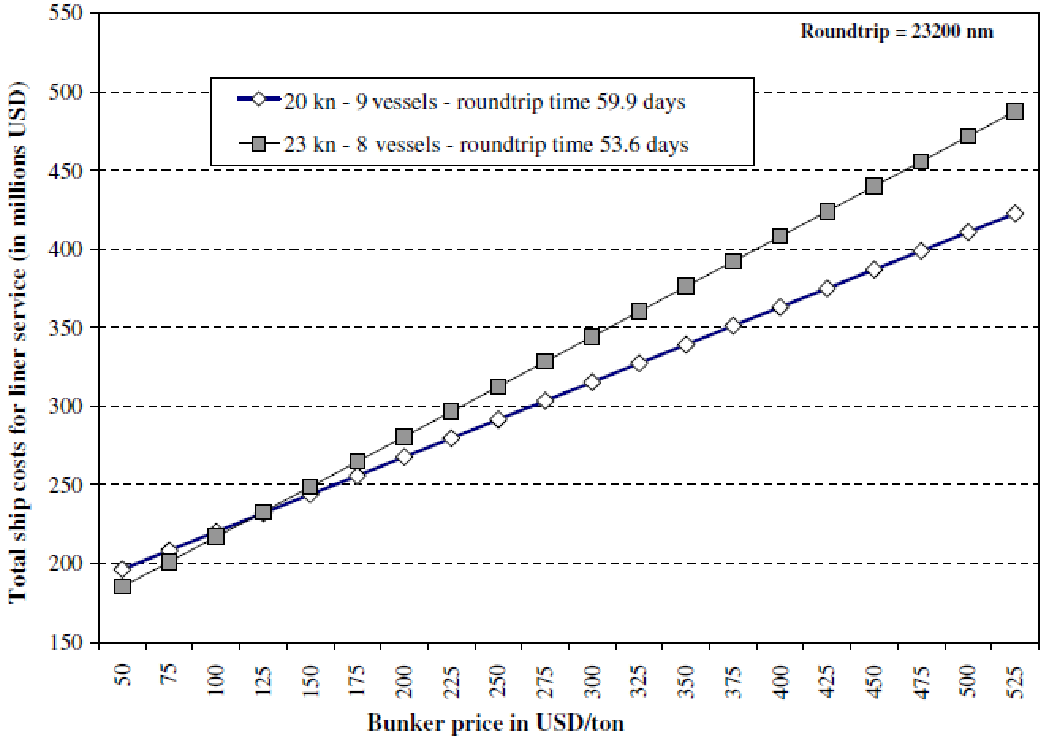


Figure 9: Total liner service costs as a function of the bunker price. Roundtrip of 23,200 nm and 10 ports of call (Notteboom and Vernimmen, 2008)

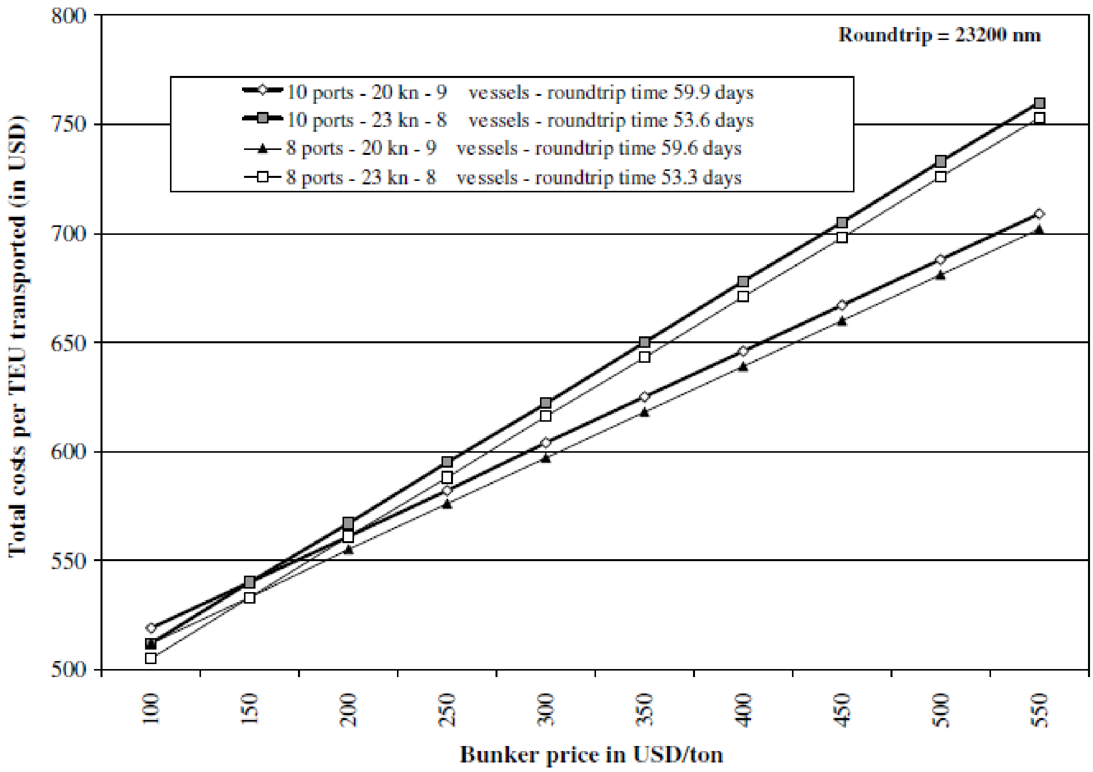


Fig. 7. Total costs per TEU transported as a function of the bunker price. Roundtrip of 23,200 nm.

Figure 10: Total costs per TEU transported as a function of the bunker price (Notteboom and Vernimmen, 2008)

Commercial issues aside, the environmental factor is certain to be more significant in the years ahead. According to Psaraftis and Kontovas (2009a), just the top tier of the world containership fleet (over 4,400 TEU) produces total CO2 emissions slightly above those of the entire world tanker fleet (2007 data). The drive to reduce ship air emissions is speculated to impact the containership sector more than anything else. In fact, designing containerships of significantly lower operating speeds is likely to be the norm for the future. Germanischer Lloyd (GL) first suggested slowing down some four years ago –and today, the idea has been accepted by most shipping lines in the container trade, said a GL spokesman. *"A green ship is an efficient ship. We recommend that shipowners consider installing less powerful engines in their newbuildings and to operate those container vessels at slower speeds,"* he said (Lloyds List, 2008a). By 'slower speeds' it is understood that the current regime of 24-26 knots would be reduced to something like 21-22 knots. But some trades may go as low as 15-18 knots, according to a 2006 study by Lloyds Register (Lloyds List, 2008b). If this happens, it would totally transform the sector.

Reducing speed may seem like a win-win proposition at first glance, as it simultaneously achieves cost reduction and emissions reduction. However, speed reduction may have other ramifications as regards the logistical supply chain, such as the necessity to add more ships and an increase of in-transit inventory costs. Thus, more analysis is necessary to identify under what circumstances speed reduction is advisable (for an analysis of some of the relevant trade-offs see Psaraftis and Kontovas (2009b)).

5. Conclusions

This paper has discussed various issues connected with liner shipping costs, as viewed through some selected references. Through that literature we have also tried to identify the most important variables that affect these costs, mainly related to economies of size, the effect of port time, speed and route distance, and bunker costs.

The conclusions reached in the above-mentioned studies have suggested that empirical data do not support the hypothesis that unit costs necessarily decrease with increments of vessel size, nor that TEU-mile cost decreases as ship size increases. Instead, the economies of container ship voyages appear to depend on many factors unrelated to size, such as route characteristics, freight rates, load factors, and the shipbuilding market. However, it is rather evident that the effects of economies of scale are especially important for the fixed costs of the ship.

Larger ships are also faster and capable, therefore, of providing a better service and better utilisation of assets. On the negative side, larger ships need to tackle additional challenges. They are often harder to handle due to more demanding requests, in terms of both money and time, related to navigation channels along rivers/canals, port's berthing draught, port access channels and cargo handling facilities. The major weakness of only analysing ship-related cost is that such an approach neglects the potential externalities imposed on other components of the logistical supply chain.

Other conclusions suggested that the overall efficiency of a ship depends ultimately on the total time the ship takes to complete a voyage. So, there is a trade-off between the positive returns earned at sea and the negative returns while in port. Port time depends on total cargo exchange, crane density, average crane productivity, non-productive time in port, working time in port, etc. Dramatic improvements in port productivity have been experienced in recent years. Empirical results suggested that economies of ship size are enjoyed until about 8,000 TEU, while within certain voyage lengths, the diseconomies of ship size in port are outweighed by economies of size at sea. Indeed, results also suggested that the benefits from scale economies in ship size decline as route lengths shorten. Therefore, the deployment of large containerships is likely to depend most crucially on voyage distance.

Analyses have also suggested that a small increase in service speed may result in a dramatic increase of fuel consumption. However, it is true that the scale increases in vessel size have resulted in lower bunker costs per slot. Other approaches concern lower vessel speeds and adding new ships to service routes to allow more efficient scheduling. Environmental considerations will certainly be a factor pushing for slower speeds in the future and the container sector will be a prime target for such practices.

With the liner industry facing the effects of the world economic crisis these days, it is very pressing to be able to know how each of these variables impacts total costs, so that the latter can be reduced. Surely optimization techniques for the broad spectrum of strategic, tactical and operational problems of liner shipping may also be relevant in that regard. Due to paper size limitations, the survey and development of such methods was outside the scope of this particular paper (see however Gkonis et al (2009) for a related discussion). It is noted that the authors and their colleagues at NTUA are actively engaged in such an investigation, whose output will be presented in future publications.

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