19

The Economics of Ships

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19.1 Introduction

It is fair to say that the overall literature in the broad area of ship economics is immense, covering a vast array of topics, ranging from the economics of the various market segments to techno-economic aspects of ship design, from shipping network design to legal-regulatory aspects of the markets, from ship routing and scheduling to safety and security, and from the economic impact of air emissions to port and terminal management, to name just a few. It is clearly impossible to cover all this material in this chapter, and the reader is referred to a number of seminal works, for instance McConville (1999), Grammenos (2002) and Stopford (2009).

Rather, the purpose of this chapter is to focus on selected aspects of the economics of ships, and highlight a few issues that are important today and likely to be even more significant in the years ahead, with no attempt at being encyclopedic. To that end, in addition to a review of the main criteria governing the economics of ships, two distinct perspectives are developed: (1) considerations of how to optimize the economic performance of a ship, and (2) considerations on how to incorporate risk into the economics equation. To achieve this, the rest of this chapter is structured as follows. Section 19.2 discusses basic criteria. Section 19.3 discusses the optimization of a ship's economic performance, with the main focus on speed optimization. Section 19.4 discusses the issue of risk management. Finally, Section 19.5 presents this chapter's conclusions and discusses areas where further research is necessary.

19.2 Basic Criteria

Ships being investments like any other, the traditional set of criteria used to evaluate investments in any industry can also apply to ships. However, special considerations are warranted, so as to capture the special characteristics of the environment in which ships operate during their lifetime.

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19.2.1 Net present value

Let us start with the traditional net present value (NPV) criterion, which is defined as follows:

$$NPV = \sum_{t=0}^{N} \frac{I(t) - C(t)}{(1+i)^t} \qquad (1)$$

Where

N = lifetime of ship (years)
I(t) = Income generated by ship in year t (t = 0, . . . , N)
C(t) = Expenditure spent on ship in year t (t = 0 . . . , N)
i = shipowner's cost of capital (assumed constant).

I(t) and C(t) are supposed to include everything that will go into or out of the shipowner's pocket during the entire ship construction, operation and scrapping cycle. These include the down payment for the ship's contract, loan amounts received and paid, interest, taxes, all operating expenses paid for by the shipowner, amounts received when the ship is scrapped and, obviously, charter revenues.

According to the NPV criterion, the ship or combination of ships that yields the maximum possible NPV is the best alternative for the shipowner. However, the apparent simplicity of this criterion is deceptive, mainly because of the significant uncertainties associated with all elements in the NPV formula. For instance,

1. The income stream I(t) is subject to the vagaries of the markets in which the ship will operate through its lifetime, and also depends on the way the ship will be utilized (which markets or trades it will serve, what cargoes it will carry).
2. The cost stream C(t) is also uncertain, as it depends on variables such as fuel prices, which are not known with certainty, but also on uncertainties as regards repairs, maintenance and other costs. It also depends on how the ship will be utilized (what routes it will serve, what cargoes it will carry).
3. Last but not least, the cost of capital i may not be known throughout a ship's lifetime (let alone a constant), not to mention that N itself is also unknown.

Yet in spite of such uncertainties (of which more in Section 19.4), the NPV criterion is widely used and can be useful in maritime transport. To make it so, the utmost care should be exercised to compute all elements of the formula as well as possible, or, if this cannot be done, to perform a comprehensive sensitivity analysis. Also, some typical safeguards should be observed. These include the following:

1. Avoid meaningless comparisons. For instance, it would not make much sense to compare a 50,000 DWT bulk carrier with one of 100,000 DWT (comparing two 50,000 DWT ships with one 100,000 DWT ship would make better sense).
2. Pay attention to different life cycle durations. It would not make sense to compare a ship for which N = 20 with a ship for which N = 30 (comparing three cycles of 20 years each with two cycles of 30 years each would make better sense).
3. Verify the independence of investments, or lack thereof. For instance, two identical ferries serving a particular market will not necessarily bring double

the income of one ferry, if demand is split between the two.

19.2.2 *Required freight rate*

A criterion closely related to NPV that is used very often in maritime transport is the required freight rate (RFR), defined thus: If we assume that I(t) = FX(t), where X(t) is the cargo carried by the ship in year t and F is a constant freight rate, then the RFR of a ship is defined as the freight rate F for which the NPV associated with the ship throughout its lifetime is zero. According to the RFR criterion, the ship whose RFR is the lowest in a group of ships is the best.

RFR is a widely used criterion to compare ships from a cost-effectiveness viewpoint. Yet, it suffers from at least the same deficiencies and limitations as NPV. For instance, being a ratio, it cannot say anything about the scale of the investment. Yet it is known that larger ships will typically have a lower RFR than smaller ships because of economies of scale, which makes this criterion biased in favor of larger ships. Also, a constant freight rate F is seldom (if ever) experienced by any type of ship, an exception being a ship engaged in a very long-term charter in tramp trades. Last but not least, trying to predict X(t) is no less difficult than trying to predict the market throughout a ship's lifetime.

In spite of all these, RFR is frequently used as a criterion, mainly to compare alternative designs or alternative investment choices. It is thus very important to avoid some pitfalls, if RFR is to be used at all.

The following considerations are important in this respect:

1. Make sure to compare ships of similar size. It would not make much sense to compare the RFR of a 500-TEU feeder with that of the *Emma Maersk*.
2. In addition to RFR, try also to compute the NPVs of the various alternatives. NPV is a more sound criterion, as a shipowner is more interested in what money he or she will make through a ship's lifetime than what value a particular ratio will take on.
3. Make a thorough sensitivity analysis.

19.2.3 *Internal rate of return*

In addition to NPV and RFR, other criteria are used in maritime transport. Among these, one can mention the internal rate of return (IRR), defined as the interest rate i in equation (1) that produces an NPV of zero. According to this criterion, the ship that has the highest IRR among ship alternatives is the best.

The following caveats are worthy of note if this criterion is used:

1. Like RFR, IRR is a ratio, and, as such, ignores scale. Therefore, we have to make sure we compare ships of similar size.
2. The root of the equation NPV(i) = 0 may not be unique, and if this is the case IRR is ambiguous.

19.2.4 *Who pays for what*

The NPV equation (and, by extension, those for RFR and IRR) may be easy to write, but what should count in these equations is not necessarily unambiguous. For instance, fuel is paid for by the shipowner if the ship operates under a voyage charter, whereas it is being paid for by the charterer in the case of a time charter. Crew expenses are typically paid for by the owner, except in the case of a bareboat charter, when they are paid for by the charterer. Cargo-handling expenses in ports may be paid by either party (or by both), depending on the contract. For instance, container terminals typically charge the ship for cargo handling between the ship and the container yard, and the cargo owner for cargo handling between the yard and the gate, as well as storage. In this case we may have multiple parties, including the shipowner, the company that charters the ship and the cargo owner, not to speak of forwarders and other agents.

It is of course impossible to know in advance how a ship will be utilized through its entire lifetime, part of which may be under voyage charter and part under time charter, among other uncertainties. So it is very important, whenever these formulae are used, to specify very clearly for whom they are being applied, and what the specific assumptions used in the calculations are.

19.2.5 Cost breakdown

Provided the issue of who is paying what is clarified, a typical cost breakdown is the following:

Capital costs Ship construction, ship retrofitting, ship major repairs (if applicable).

Crew expenses Wages, overtime, pensions, accident–sickness insurance, traveling–repatriation, provisions, victualing and cabin stores, etc.

Vessel expenses Fuel; stores / spares, lubricants, maintenance / minor repairs, annual survey, fresh water, communication charge; insurance: hull and machinery, war risks, freight demurrage defense, protection and indemnity, other marine risks, etc.

Cargo expenses These include, as applicable, cargo inspection, customs examination, documentation, stuffing, stripping, measuring / weighing, tallying.

Terminal handling charges These include, as applicable, loading, unloading, receiving, delivery, transshipment, storage, overtime surcharge.

Port charges Pilotage, towage, dockage, wharfage, harbor, tonnage, light, buoy and anchorage dues, mooring and unmooring, running lines, customs and quarantine fee, watchman agency, canal fees, etc.

*Administrat***ive** *expenses* Salaries and wages of employees, benefits, rental expenses, office expenses, communication expenses, dues and subscriptions, travel expenses, advertising, entertainment and solicitation, legal fees, taxes, etc.

19.2.6 Important additional considerations

19.2.6.1 Shipbuilding and scrapping The price of a ship when it is built enters NPV calculations directly, and so does the amount received when the ship is scrapped. Both prices vary widely, as functions of ship type and size and the state of the market at the time the transaction takes place. Needless to say, the scrapping price of a ship twenty years into the future is an unknown quantity, so best estimates from current values should be used.

19.2.6.2 Loans and interest In the NPV equation (and, by extension, in the equations to compute RFR and IRR), loans are treated like any other cash stream:

positive for loan receipts (to finance part of ship construction costs), and negative for repaying capital and interest. The loan interest rate R is not necessarily equal to i, the shipowner's cost of capital, and is the subject of negotiation between the lender and the shipowner. The loan payback scheme also depends on the terms that have been agreed between the lender and the shipowner.

19.2.6.3 Depreciation Caution should be exercised with regard to the treatment of depreciation. Depreciation is *not* a cost that enters NPV calculations directly, but accounting-wise it is a cost that enters the company's books, and its connection with NPV is only indirect. The connection is only via the taxes that are paid, which typically take depreciation into effect (see below). There may be various depreciation schemes, concerning both the depreciation period, and the depreciation amounts per year, which may or may not be constant over time. The depreciation period is typically shorter than the economic lifetime of the ship.

19.2.6.4 Taxes Taxes are also treated in the NPV equation as an outgoing cash stream. The magnitude of taxes depends on the tax laws instituted by the ship's flag. Certain countries have a "tonnage" tax, taxes being functions of tonnage, and in others, tax is a function of taxable income. Typically, interest and depreciation costs are tax-exempt. Attention should be paid to how taxes are calculated in the RFR equation, as the freight rate that is computed by the NPV = 0 equation may not be possible to calculate in closed form but only by iterations.

19.3 Optimizing Ship Economic Performance

19.3.1 Speed as a decision variable

Predicting streams of income and expenditures over a ship's entire lifetime involves significant uncertainties (of which more in Section 19.4). However, it is clear that both depend on the way the ship is utilized. This can have an important impact on NPV, RFR, IRR and other criteria.

Among the many decision variables affecting ship utilization, a very important one is speed, for a variety of reasons. First, speed is the main determinant of fuel cost, a significant component of a ship's operational cost. Speed is also one of the main factors that determine how much throughput (expressed in tonne-km) is produced by the ship, something that is directly linked with its lifetime revenue.[1] Here we highlight the main issues involved.

For a variety of reasons, mainly (but not solely) related to the drive to reduce costs, speed reduction has become a popular measure, particularly in depressed markets such as those after mid-2008. A spokesman from Germanischer Lloyd (GL) has been quoted as follows: "We recommend that ship-owners consider installing less powerful engines in their newbuildings and to operate those container vessels at slower speeds" (*Lloyd's List* 2008a). By "slower speeds" it is understood that the current regime of 24–6 knots would be reduced to something like 21–2 knots. But some trades may go as low as 15–18 knots, according to a 2006 study by Lloyd's Register (*Lloyd's List* 2008b), and perhaps even lower. GL executive board member Hermann Klein predicted that 14 knots, or perhaps even lower, would become the norm for container ships

(*Lloyd's List* 2009b). Det Norske Veritas's Chief OO Tor Svensen has been quoted in saying that speed reduction and other measures could reduce emissions by 30% by 2030 (DNV 2009). However, in what may be a difference of opinion, Bureau Veritas' chief Bernard Anne said "owners should retain as much flexibility as possible, and continue with ships able to operate efficiently over a broad range of speeds" (*Lloyd's List* 2009b).

In practice, what is termed "super-slow steaming" has been pioneered by Maersk Line, the world's largest container carrier, after trials involving 110 vessels at the beginning of 2007. Maersk Line's North Asia Region CEO, Tim Smith, said that trials showed it was safe to reduce the engine load to just 10%, compared with the traditional policy of reducing the load to no less than 40–60% (see TradeWinds 2009). For container ships 10% engine load means sailing at about half of the design speed. Furthermore, in late 2009, China Ocean Shipping (Group) and its partners in the CKYH alliance – K Line, Yang Ming Marine and Hanjin Shipping – were also reported to be introducing super-slow steaming on certain routes (*Lloyd's List* 2009a).

Whatever the merits or demerits of speed reduction, it is clear that slow steaming can be realized at two levels: The first level is truly operational, that is, have a ship that is designed to go at 26 knots sail at a lower speed, say 24, 20, or even 16 or 14 knots. Depending on what the slow steaming speed is, speed reduction may or may not entail reconfiguring the engine so that it performs well under a reduced load. One of the main determinants of slow steaming speed is fuel price, owners being prone to reduce speed if fuel prices rise. Another determinant is the state of the market, owners being prone to reduce speed in a market slump but increase it in a market boom.

The second level of slow steaming is strategic: build future ships with smaller engines so they can only sail (say) 14 knots instead of 26. The main difference between the two levels is that the first is reversible whereas the second is not. One can always configure back a "de-rated" engine, but installing a larger engine on a ship that has been built with a small engine is either very expensive or impossible. And if the ship with the smaller engine attempts to sail at a higher speed, its fuel consumption will likely be higher than if the engine were more powerful. Implementing a speed reduction scheme in a strategic setting would involve modifying the design of the ship, including its hull shape, installing smaller engines in future newbuildings, and modifying the propeller design and other features.

Speed optimization is not a new idea. Ronen (1982, 2011) examined the impact of fuel prices on optimal speed. Perakis and Papadakis (1987) examined the issue in the context of fleet deployment. Andersson (2008) considered the case of a container line which reduced the speed for each ship from 26 knots to 23 knots and added one more ship to maintain the same throughput. Total costs per container were reduced by nearly 28 per cent. Eefsen (2008) considered the economic impact of speed reduction of container ships and included the inventory cost. Cerup-Simonsen (2008) developed a simplified cost model to demonstrate how an existing ship could reduce its fuel consumption by a speed reduction in low and high markets to maximize profits. Corbett, Wang and Winebrake (2009) applied fundamental equations relating speed, energy consumption and total cost to evaluate the impact of speed reduction.

They also explored the relationship between fuel price and the optimal speed. Notteboom and Vernimmen (2009) examined bunker fuel costs, which are a considerable expense in liner shipping. Their paper assessed how shipping lines have adapted their liner service schedules to deal with increased bunker costs, which includes the examination of speed reduction scenarios. Last but not least, Psaraftis and Kontovas (2009, 2010) investigated trade-offs between ship emissions and operational costs.

The wish for slow steaming may have many causes. The main incentives for speed reduction are:

1. higher or volatile bunker prices leading to increased fuel costs;
2. higher bunker costs due to the obligation to use the more expensive Low Sulfur Fuel Oil, for example when operating in Sulfur Emission Control Areas (SECAs);
3. savings in other running costs components (e.g., port dues and local taxes);
4. overcapacity resulting in reduced freight rates;
5. mandatory emission-related regulations; and
6. voluntarily emission-related regulations, mainly adopted by companies that want to take responsibility for their impact on society.

The effect of high fuel prices on speed is not new. Ships (especially tankers) sailed at lower speeds during the oil crises of 1973 and 1979. In 1972 the price of crude oil was about US$3 per barrel. By the end of 1974 oil prices had quadrupled, to over US$12 per barrel. The second oil crisis came with the combination of the Iranian revolution and the Iran–Iraq war, which caused oil prices to increase from US$14 in 1978 to US$34 per barrel in 1981. For a consideration of the impact of fuel prices on very large crude carrier (VLCC) spot rates, including a discussion of optimal VLCC speed as a function of fuel prices, see Devanney (2010).

Even in non-volatile markets, fuel costs increase because of the need to use more expensive fuel, for example the need to use low sulfur fuel oil (LSFO) when sailing in (SECAs). The IMO unanimously adopted amendments to the MARPOL Annex VI regulations, and the main changes will see a progressive reduction in sulfur oxide (SO_x) emissions from ships (IMO 2008a). Furthermore, the Californian Air Resource Board (CARB) has since July 1, 2009 enforced the use of marine diesel oils (MDO) or marine gas oils (MGO) in Californian waters. Last but not least, when at berth in EU ports, vessels must as of January 1, 2010 use marine fuels with a sulfur content not exceeding 0.1% by mass (EU directive 2005/33/EC, Article 4a), something that is expected to create a problem in the short run, as many vessels are not yet ready to implement the measure. In all the above cases "cleaner" fuel means "more expensive" fuel.

High fuel costs will always make ship operators investigate possible ways to reduce fuel consumption. The easiest way to reduce fuel bills is to sail more slowly. In turn, the most likely result of such slow steaming is the shrinking of the fleet capacity supply curve, which typically leads to higher freight rates, and (as a result) to profits that may be higher than the extra costs due to more expensive fuel.

This brings up an additional reason for slow steaming. Back in the early 1970s many tanker owners adopted drastic measures, including slow steaming, because of an over-tonnaged sector as a result of the newbuildings order book. The same is true today, and not only for tankers. It is not a coincidence that speed reductions are currently being observed within the container market. Container fleet growth has been exceeding transportation demand. Fleet overcapacity has resulted in reduced freight rates. This has in turn enabled speed reductions, an effective means of shrinking the fleet supply curve. It is known that many ships are to be delivered between 2010 and 2012, leading to an over-capacitated container market. However, it is not easy to guess the consequences of this oversupply, since we cannot predict the trend in demand. Lately, because of slow steaming, many companies had to add more ships to their routes to maintain throughput (note, for example, the additional ships deployed on the Far East–Northern Europe routes). This can lead to higher rates.

19.3.2 A simple model

To see the effects of speed reduction, let us examine a simple model. Assume that the daily fuel consumption F at sea at speed V is a cubic function of speed V. The cubic law follows from hydrodynamic principles and is a standard assumption in most analyses. If this assumption does not hold, a similar analysis can be made.

Psaraftis and Kontovas (2009, 2010) investigated a simple logistical scenario. The scenario assumed a fleet of N identical ships (N: integer), each of capacity (payload) W. Each ship loads from port A, travels to port B with known speed V_1, discharges at B and goes back to port A in ballast (empty), with speed V_2. Assume speeds are expressed in km per day. The distance between A and B is known and equal to L (km) and the total time in port at both ports is T_{AB} (days). Assume these ships are chartered on a term charter and the charterer, who is the effective owner of this fleet for the duration of the charter, incurs a known operational cost of O_C per ship per year. This cost depends on market conditions at the time the charter is signed; it includes the charter to the shipowner and all other non-fuel-related expenses that the charterer must pay, such as canal tolls, port dues and cargo-handling expenses. Not included in O_C are fuel expenses, which are also paid by the charterer, and which depend on the actual fuel consumed by the fleet of ships. The latter depends on how the fleet is used.

Assume that each ship's operational days per year are D ($0 < D < 365$), a known input, and that the total daily fuel consumptions (including main engine and auxiliaries) are known and are as follows for each ship: f (tonnes per day) in port, and F_1, F_2 (tonnes per day) at sea for the laden and ballast legs respectively.

As stated earlier, the effect of speed change on fuel consumption is assumed cubic for the same ship, that is, $F_1 = k_1 V_1^3$ and $F_2 = k_2 V_2^3$, where k_1 and k_2 are known constants (typically $k_1 > k_2$).

In addition to the standard costs borne by the charterer, Psaraftis and Kontovas (2009, 2010) took into account **cargo inventory costs**. These costs are assumed equal to I_C per tonne and per day of delay, where I_C is a known constant. In computing these costs, it is assumed that cargo arrives in port "just-in-time", that is, just when its ship arrives. Thus, inventory costs accrue only when loading, transiting (laden) and discharging. These costs are called "in-transit inventory costs." Generalizing to the case where inventory costs due to port storage are also considered is straightforward.

If the market price of the cargo at the destination (cost, insurance and freight – CIF – price) is P(US$/tonne), then one day of delay in the delivery of one tonne of this cargo will inflict a loss of PR/365 on the cargo owner, where R is the cost of the cargo owner's capital (expressed as an annual interest rate). This loss is the income lost through the delay in selling the cargo. Therefore, it is straightforward to see that $I_C = PR/365$.

Let us now assume that the speed of all ships in the fleet is reduced by a common amount $\Delta V \geq 0$. To keep annual throughput constant, we have to add more ships, assumed identical in design to the original N ones. If $V_1 = V_2 = V$ (this may not mean that $k_1 = k_2$), the difference in total fleet costs (costs after minus costs before) is equal to:

$$\Delta(\text{total fleet cost}) = NL\Delta V \frac{-pD(2V - \Delta V)(k_1 + k_2) + \dfrac{I_C WD + 2O_C}{V(V - \Delta V)}}{2\dfrac{L}{V} + T_{AB}} \quad (2)$$

The difference in fuel costs alone is equal to

$$\Delta(\text{total fuel costs}) = -NL\Delta V \frac{pD(2V - \Delta V)(k_1 + k_2)}{2\dfrac{L}{V} + T_{AB}} \quad (3)$$

An interesting observation is that fuel cost differentials (and, by extension, total fleet cost differentials) are independent of port fuel consumption f. This can be explained by noting that the new fleet string, even though more numerous than the previous one, will make an equal number of port calls in a year; therefore fuel burned while in port will be the same.

It is also interesting to note that for $\Delta V \geq 0$ and for all practical purposes the differential in fuel costs is always negative or zero, as difference $2V - \Delta V$ in (3) is positive for all realistic values of the speeds and of the speed reduction. This means that speed reduction cannot result in a higher fuel bill, even though more ships will be necessary.

This result can be generalized to logistical scenarios that are more complex than the one examined here, for instance one that involves a ship which visits a set of ports and is less than full (which is typically the case for container ships). The core result from this analysis is that total fuel costs will always be reduced by slowing down, even though more ships would be used. The higher the speed, and the greater the speed reduction, the greater this emissions reduction will be. The theoretical maximum reduction will occur if we reduce speed all the way to zero, in which case both fuel costs and emissions will also be zero. Of course, such a scenario would not make any sense, as no cargo would be moved and hence cargo inventory costs and total costs would go to infinity. By the same token, a scenario of super-slow speed may suffer from similar problems.

19.3.3 When is speed reduction cost-beneficial?

Even though Δ(total fuel cost) is always negative or zero, Δ(total fleet cost) may be positive or negative, or may reach a minimum value other than zero, depending on the values of all the parameters involved.

One can see that in-transit inventory costs and operational costs count positively in the cost equation. Both these costs would be increased by a reduction in speed, and this increase might offset, or even reverse, the corresponding decrease in fuel costs. High values of either I_C or O_C (or both) would increase the chances of this happening, and high values of the fuel price p would do the opposite.

Psaraftis and Kontovas (2009) presented some examples to illustrate this approach, for tankers, bulk carriers and container ships. Of these, perhaps the most interesting was the one that investigated the effect of a speed reduction of just 1 knot (from 21 to 20) in a fleet of 100 Panamax container ships. The example showed that if the sum of additional cargo inventory costs plus other additional operational costs of the (five) extra ships that would have to be used (including the time charter) is less than US$128,299 per extra ship per day, then speed reduction is overall cheaper. One would initially think that such a threshold would be enough. But it turns out that this is not necessarily the case if in-transit inventory costs are factored in.

In that regard, we note that the unit value in US dollars per short ton[2] of the top twenty containerized imports at the Los Angeles and Long Beach Ports in 2004 varies from 12,600 for furniture and bedding to 86,200 for optic, photographic and medical instruments (see CBO 2006).

To compute in-transit inventory costs for the above example, we hypothetically assume that cargo carried by these vessels consists of high-value industrial products, similar to the top twenty imports mentioned above, and that its average value at the destination (CIF price) is US$20,000/tonne. We also assume the cost of capital is 8%. This means that one day of delay of one tonne of cargo will entail an inventory cost of $I_C = PR/365 =$ US$4.38/tonne/day. Computing the in-transit inventory costs for this case gives a total annual difference of US$200,000,000 in favor of the case that moves cargo faster. This figure is significant, of the same order of magnitude as the fuel cost differential. Assuming a time charter rate of US$25,000 per day (the typical charter rate for a Panamax container ship in 2007), the total other operational costs of the reduced-speed scenario are computed at US$958,125,000 per year for the reduced-speed fleet ships (105 ships), versus US$912,500,000 for the fleet of ships going full speed (100 ships). Tallying up we find a net differential of US$11,478,741 per year in favor of not reducing the speed, meaning that for this scenario in-transit inventory and other operational costs can offset the positive difference in fuel costs.

It should be realized that cargo inventory costs are borne by the owner of the cargo, whereas the other cost components are borne by the shipowner and the charterer of the vessel, their distribution depending on the type of contract. This means that whatever is good for one of these parties may not necessarily be good for the other. But on a total cost basis, the example above shows that speed reduction may not necessarily be cost-beneficial overall (and note that possible freight rate increases due to reduced ship capacity, also borne by the cargo owner, are not taken into account in our model).

19.3.4 Optimizing fleet operation

Speed optimization is only one of several decision variables within the broader spectrum of problems related to the optimization of a ship's economic performance. The broader picture involves optimizing the operation of a fleet of ships, or, by a further extension, of the entire intermodal chain, including ports.

To see this broader picture, one would need to examine one or more of the problems in the following generic list (which is not exhaustive):

- optimal ship speed
- optimal ship size
- routing and scheduling
- fleet deployment
- fleet size and mix
- weather routing
- intermodal network design
- modal split
- transshipment
- queuing at ports
- terminal management
- berth allocation
- supply chain management.

Many of these problems methodologically fall under the disciplines of operations research – management science – transportation logistics problems, whose objective is to optimize one or more aspects of the operation of a ship, a fleet, or a supply chain system.

It is clearly outside the scope of this chapter to provide a complete bibliographic survey of this very broad variety of problems, except to state that the literature on these problems is rapidly growing. See, for instance, Christiansen, Fagerholt, Nygreen and Ronen (2007) for surveys of ship routing and scheduling problems, Brown, Graves and Ronen (1987) for the scheduling of crude oil carriers, Fagerholt (2004) for vessel fleet scheduling, Thompson and Psaraftis (1993) for local search methods, Rana and Vickson (1991) for routing of container ships, and Agarwal and Ergun (2008) and Alvarez (2009) for optimization approaches in liner shipping. For terminal management problems, a branch and cut procedure is reported by Moccia, Cordeau, Gaudioso and Laporte (2006), and the so-called "double cycling" procedures for loading and unloading are described by Goodchild and Daganzo (2006). For reviews of the operations research literature of problems related to container terminal management the reader may refer among others to Vis and de Koster (2003) and Steenken, Voss and Stahlbock (2004). Also, a comprehensive literature survey, with some 157 related references, is presented in Stahlbock and Voss (2008).

However, in spite of the growing literature, many of these problems are typically treated in isolation from one another, even though many of them are interconnected. For instance, the problem of optimal loading of a container ship is connected with the problem of optimal yard management, which in turn is connected with the problems of routing straddle carriers in the terminal, assigning cranes to ships when they berth, berth allocation, determining optimal queuing strategies, selecting which port should be a transshipment port, network design, and so on. All of these problems impact, directly or indirectly, the economics of ships (including the basic criteria of Section 19.2), but no good way to treat them holistically is yet known.

19.4 Risk Management

A very different but equally important dimension of ship economics deals with risk management. Here we are not talking about accident risk and the related subject of maritime safety, which also has economic implications, but about financial risk. This is very important because of the high degree of uncertainty involved in most aspects of a ship's economic performance (as alluded to in Section 19.2 above). The term "risk management" refers to situations which could lead to a decline in the value of a shipping firm, arising from events or various factor changes influencing expected cash flows.

Some basic classes (sources) of risk in ship economics can be identified (Alizadeh and Nomikos 2009; Kavussanos and Visvikis 2006). They are discussed below.

19.4.1 Price risk

19.4.1.1 Freight-rate or business risk
Freight- rate risk is caused by the volatility of the earnings of a shipping company from the freight rates. This is the fundamental origin of risk in a shipping company. The notorious volatility of the Baltic Dry Index, for example, which is very common in the tramp sector of the shipping industry (where there is perfect competition), and the occurrence of catastrophic structural breaks in terms of the evolution of freight rates, force investors to use risk management strategies, such as time-chartering the vessels or contracts of affreightment (COAs).

These classical approaches, however, imply other physical risks, and shipowners lose the control of their ship for the duration of the contract. Therefore, derivatives have recently become quite popular, as they mitigate market risk via a paper market, where one can open and close long/short positions much faster, more simply and at a lower cost. Derivatives also offer portfolio management capabilities. What is more, positions in freight derivatives are viewed positively for a shipping company, in a similar manner to time charter, when a company negotiates a loan with a bank.

Freight derivatives offer other advantages: fixation of cash flows for a time horizon of up to three years; the flexibility to buy or sell positions prior to expiry; ease of closing out positions; and price discovery, as it may be assumed that freight derivatives discount future developments. Freight derivatives are purely financial transactions, with no physical performance, that do not affect the physical operation of vessels, control of which is kept in the hands of the shipping company. There are no requirements with the physical operation; and control of the vessels is kept in the hands of the shipping company. Freight forward agreements (FFAs) are rather simple for someone to start trading, but a possible market manipulation has been shown to be possible, in practice. Another disadvantage is the lack of a secondary market for over-the-counter, i.e. customized, contracts, and furthermore, the closing out of a contract is difficult in routes with low liquidity for the same settlement month. The problem of counterparty risk also exists, because private equity shipping firms are not obliged to publish accounting data. FFAs can create extremely high aggregate losses before they expire, in contrast to futures contracts, where there is a daily mark-to-market system.

A typical FFA is considered to be a contract for difference (CFD) between two parties settling a freight rate for a given cargo volume per ship category, for one or a combination of the major trade routes in the dry-bulk/tanker sectors. The underlying assets in this derivative type are based on the Baltic Panamax Index (BPI), the Baltic Capesize Index (BCI), the Baltic Supramax Index (BSI) or the Baltic Handysize Index (BHSI) in the dry-bulk sector, for example. Each index is calculated as the weighted average of the freight rates of a number of important trading routes for a given cargo and vessel size.

Generally, freight derivatives can be used as hedging instruments for shipping companies operating on given routes. This *can* happen not only because charterers have opposite interests and a preference for fixing their shipment costs, but also because there exist market agents who have different views about the fair value of the derivatives contracts, or the future evolution of freight rates. On the other hand, sometimes the spread in the prices between two shipping lines and vessel sizes, which is (according to historical data) not justified, signals traders to get into speculative trading (statistical arbitrage).

19.4.1.2 Operating costs risk Operating costs are related to broking commission, canal fees, tug boat use, maintenance and repairs, stores and lubricants, administrative expenses and wages, but the most significant factor is bunker costs.

Besides freight-rate variability, volatility in terms of costs is a factor influencing the profit margin of shipping companies. The most critical cost element is the price of bunkers for the vessel during a voyage. According to Stopford (2009) this accounts for approximately 50–60 percent of the total voyage costs, and spikes in bunker prices have repercussions on the profitability of shipping companies and ship operators. Bunker prices depend on oil prices, stock levels, geopolitical events, weather conditions, refinery practices, and bunker price competition between ports.

Because of this high variability, it is vital that market participants manage their exposure to bunker market fluctuations, in order to ensure positive net operating cash flows. For this purpose specialized financial derivatives have been developed, such as the over-the-counter (OTC) forward bunker agreements, where two parties (long/short side) decide on the delivery at an agreed price, quantity and quality of fuel, at a specified delivery location and time. Of course, oil futures contracts traded at International Exchange (ICE) and International Petroleum Exchange (IPE) may be used, allowing higher maximum leverage, ease in closing out positions (unlike forward contracts (OTC)), and ensuring no credit risk, due to a mark-to-market system in clearing.

What is more, bunker swap agreements, which are also traded OTC, have been introduced for hedging oil price risk, by exchanging a floating price for bunkers for a fixed rate, over a given time period and for a given quantity. More sub-periods may be defined in the contract and there is no physical delivery, but by combining it with purchases or sales of oil in the physical market, hedging can be achieved.

Liner shipping companies can use surcharges, as a relatively small portion of the freight rate, but generally, the perfect competition in the tramp sector and to some extent in the liner sector (where ship managers operate under oligopolistic conditions) makes it difficult for companies to pass on higher costs to higher freight rates. Thus, hedging at around 50 percent of a two-year exposure for shipping companies is very common, but incomplete elimination of the risk is popular, since there is a tendency to attempt to speculate on oil price market moves.

19.4.1.3 Interest rate risk Interest rate risk derives from fluctuations in lending rates, which accentuate the financial problems of shipping companies (already at a high leverage ratio, as is quite common in the industry) when interest rates increase and firms must refinance their loans at a higher floating rate. In parallel, firms may also have exposure to currency risk if the currency of their revenue is other than the denomination of their debt or operating costs.

Thus, swaps are used to mitigate interest rate risk; that is, they are agreements to exchange a series of cash flows on periodic settlement dates over a certain time period (for example, quarterly payments over two years). In the simplest version of a swap, party A makes fixed-rate interest payments on the notional capital, as agreed in the swap, in return for floating-rate payments from party B. When each settlement date comes, the two payments are netted so that only one payment is made to the party who expects to receive a positive overall inflow from the agreement. A swap can be analyzed as a string of forward rate agreements (FRAs) expiring at each settlement date.

Swaps have several advantages, such as that no payment is required by any party at the beginning and that they can be terminated by a mutual agreement, an offsetting contract resale, or another financial instrument. However, default risk exists in such an agreement. Swaps are customized, they are not traded in any secondary market, and they are mostly unregulated. What is more, so-called currency swaps can also be applied, in order to neutralize foreign exchange risk, where two parties exchange payments denominated in different currencies. A notional principal is agreed upon, expressed in both currencies at the current exchange rate. They are exchanged at contract initiation and returned at the termination date of the contract in the exact initial amounts.

19.4.1.4 Asset price risk Asset price risk – the risk that comes from volatility in the price of the assets – arises from the constantly changing value of vessels. It hits the balance sheet value of a company as well as its credit rating, since ships are also collateral in shipping finance schemes. For this reason, all market agents, i.e. ship finance banks, shipowners and ship operators, closely watch ship price volatility and take these data into consideration in their investment processes.

Alizadeh and Nomikos (2009) investigated volatility and return statistics for dry-bulk and tanker-ship prices for three different classes in terms of age (newbuildings, five-year-old second-hand vessels, and ships destined for scrap), for the period from February 1981 to May 2008, using data from Clarksons Research. They used three classifications for the major dry-bulk vessel sizes, Capesize, Panamax and Handysize. Standard deviations vary greatly, from 0.0921 to 0.24, in scrap prices for Handysize vessels. Similarly, in the tanker sector (four classes: VLCC, Suezmax, Aframax and Handysize), standard deviations ranged from 0.0791 (Newbuildings, Handysize) to 0.211 in scrap prices for Suezmax tankers. One of the major conclusions was that prices for larger vessels generally exhibit higher volatility than prices for smaller vessels, for all age groups.

In the past, there were no derivatives for vessels and, as short selling of vessels is not possible (it is only possible for equities of listed shipping companies, and then only under certain conditions), one could only take advantage of expectations about an upcoming increase in prices only, in the past. What is more, the vessel market generally has low liquidity, so price discovery and market corrections are not easy. This led to the Sale and Purchase Forward Agreements (SPFA) for the dry bulk and tanker markets, which are traded OTC. They started in 2004 and are reported every week, and calculated in the same manner as the dry and tanker freight indices, by the Baltic Exchange. They are traded in lots (20 lots = 100 percent of a ship value), and agreed in terms of settlement period and maturity according to the wishes of the trader.

19.4.1.5 Credit risk Credit risk, which has to do with the ability of a counter-party to pay their obligations, is very important in shipping given the highly cyclical nature of the industry: the total leverage can be very high and the alternation of high profits and catastrophic losses has led to excessive defaults of shipping companies for many decades. Credit risk arises as a serious issue in freight derivatives contracts, but also in business relations between shipyards and shipowners or bunker suppliers.

Banks devised so-called credit enhancements, in order to mitigate credit risk in derivatives, for example. They can use master agreements, credit support documents offering protection against credit risk, credit rating collateralization of transactions, third-party guarantees, credit insurance, letters of credit, downgrade triggers (i.e. clauses closing out the contract if the credit rating falls below a certain level according to some predetermined formula), credit derivatives (in the form of credit default swaps, total return swaps or credit spread options), or payment netting. All these measures either have the character of a collateral/guarantee/insurance from third parties or improve credit conditions for the lender.

19.4.2 Operational risk

Operational risk is the risk of drop in the value of assets caused by physical damage, accidents and losses due to physical risks, technical failure or human error in the operation of the assets of a company, or the risk of legal responsibility for damages from corporate actions. For a shipping company, for instance, operational risk includes accidents or liabilities from oil or chemical spillage.

Insurance contracts, in addition to better use of technology, are the only solution available to shipping companies that wish to mitigate the consequences of catastrophic events. Insurance and reinsurance companies can handle this risk much better since they minimize their exposure through diversification of their portfolio.

19.4.3 Hedging and basis risk

As mentioned above, in the shipping business operators resort to the use of various financial instruments called derivatives, in order to control the magnitude of the repercussions of various sources of price risk, such as freight rate levels, interest rate levels and foreign currency risk. The application of these “instruments” acts like insurance, as they offset any losses from price fluctuations in the opposite position that the firm has taken. The establishment of such positions via derivatives in order to minimize exposure to unwanted price risk is called hedging.

The basis in hedging is defined as the difference between the spot price of the asset to be hedged and the price of the forward contract used for hedging. The basis convergence may take place as the expiration date of the contract approaches, but until that moment spot prices can be higher than futures prices, in which case we have a market in **backwardation**, or lower, when we have a market in **contango**.

The basis risk is another source of risk for shipping companies, for various reasons. Operators do not know precisely when to proceed with the purchase or sale of contracts in the physical market when hedging; or they may be forced to close their position before the contract expires (e.g. in the event of a margin call when additional collateral is demanded by the broker); or the underlying asset of the derivative may be just a proxy and not exactly the target asset that they want to hedge.

19.4.4 Political risks

Any factors that affect the business which are caused by political events – wars, political turmoil in a region, canal closure, etc. – are included here. Political events have always affected international trade and shipping in parallel with global economic growth. Cases in recent history include World War II (1940–5), the Suez Canal closures (1956, 1967, 1973), and the Gulf Wars (1991, 2003).

19.4.5 Methodology for expressing exposure to risk: value-at-risk in shipping

A modern risk assessment and measurement methodology is the estimated potential loss or the "value-at-risk" (VaR). Firms use VaR to estimate market risk exposure, by translating all risks into a single number which can easily be presented to company management, shareholders, other stakeholders and regulators. The first structure of VaR can be found back in 1922 when the application of the minimum capital requirements was established in the New York Stock Exchange.

After a series of financial disasters from derivatives transactions in banks, municipalities, corporations, etc., stricter rules after the second (and now the third) Basel Accord aimed to force financial institutions to maintain minimum capital requirements, so that potential losses could not trigger crises. Thus, several risk-assessment procedures were invented and implemented to quantify and assess the overall risk of financial institutions. In 1994, J. P. Morgan published the risk-assessment method **RiskMetrics**, the framework for calculating VaR, which was adopted by industry and researchers (Satchell and Christodoulakis 2008). In shipping, this quantitative methodology started to be used only very recently, as a result of the success of the FFAs market and the participation of shipping companies in taking position in FFAs.

The calculation of VaR can be approached parametrically by computing the VaR of a portfolio (of risk factors such as freight rates, exchange and interest rates, and stock prices) on the basis of historical volatilities and correlations, by using Gauss distributions for all time series or non-parametrically by using a Monte Carlo or historical simulation.

19.5 Summary

This chapter has attempted to highlight a rather limited number of issues in ship economics that will be, in our opinion, important in the years ahead. We believe that research in these and related areas will grow further and will be useful from a practical perspective. Because of environmental concerns about air pollution from ships and the need to reduce it, it is imperative to improve the economic performance of ships to the greatest possible extent. Environmental criteria were not examined explicitly in this chapter, but as ship air emissions are directly proportional to fuel burned, it is clear that minimizing fuel consumption would also minimize emissions. To what extent this would also produce a win–win solution vis-à-vis other criteria is a subject that should be looked at.

The IMO is currently looking at an array of technological, operational and market-based measures with a view to reducing CO_2 emissions. All of these measures will surely impact the economics of ships. For instance, building a new ship so that its so-called Environmental Efficiency Design Index (EEDI) is below a certain baseline value will impact decisions on ship geometry, size, propulsion, and other parameters such as design speed. Also, the adoption of market-based measures such as a fuel levy will impact operating speed and lead to technology investments aimed at producing a greener fleet. Ideally, the external costs of ship air emissions should be internalized, and when this is taken on board the optimal ship may be different than one under a regime in which environmental criteria are absent. Therefore one would expect an increasing role for such criteria in the future.

A related, but separate, area in which environmental criteria may come into play concerns the treatment of oil pollution. As oil pollution has a definite environmental cost, which can be quantified in economic terms, the question is what measures should be adopted at the design stage so that the environmental risk is minimized. The IMO uses techniques such as Formal Safety Assessment (FSA) for regulation formulation, and these incorporate a cost–benefit step to assess the cost-effectiveness of proposed measures (see Kontovas and Psaraftis 2009).

In a broader sense, in these difficult economic times the treatment of risk, including financial risk, is of paramount importance, and models that capture the risk dimension should be of significant benefit to the shipowner. The development of holistic models that attempt to link the various sub-problems and avoid suboptimal solutions is considered important.

Notes

1 Obviously another such important variable is ship size, usually expressed by payload, or deadweight. We shall not be dealing with the impact of ship size on ship economics, as the literature on this subject is rich (see, for instance, Cullinane and Khanna 2000; Gilmamn 1999; Talley 1990).

2 1 short ton = 0.9072 tonnes.

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