Sadržaj osnovne literature:

Dopunska literatura:

- Benford, H. (1983a) A Naval Architect's Introduction to Engineering Economics (Ann Arbor, Mich.: University of Michigan, College of Engineering) No. 282.

- Čekić, Š., I. Bošnjak, MENADŽMENT U TRANSPORTU I KOMUNIKACIJAMA, Fakultet za saobraćaj i komunikacije Univerziteta u Zagrebu, Fakultet prometnih znanosti Sveučilišta u Zagrebu, Sarajevo, Zagreb, 2000.

- Dundović, Č., POMORSKI SUSTAV I POMORSKA POLITIKA, Pomorski fakultet u Rijeci i Glosa Rijeka, Rijeka, 2003.

Glavan, B., POMORSKI BRODAR – ORGANIZACIJA I POSLOVANJE, Istarska naklada, Pula, 1984.

- Hampton, M.J. (1989) Long and Short Shipping Cycles (Cambridge: Cambridge Academy of Transport), 3rd edition 1991.
- Haws, D. and Hurst, A.A. (1985) The Maritime History of the World, 2 vols (Brighton: Teredo Books Ltd).

- Jones, J.J. and Marlow, P.B. (1986) Quantitative Methods in Maritime Economics (London: Fairplay Publications).

- Stopford, R.M. and Barton, J.R. (1986) 'Economic problems of shipbuilding and the state', Journal of Maritime Policy and Management (Swansea), Vol. 13(1), pp. 27–44.

- Volk, B. (1994) The Shipbuilding Cycle-A Phenomenon Explained (Bremen: Institute of Shipping Economics and Logistics).

13 The Transport of General Cargo

The growing intricacy and variety of commerce is adding to the advantages which a large fleet of ships under one management derives from its power of delivering goods promptly, and without breech of responsibility, in many different ports; and as regards the vessels themselves time is on the side of large ships.

(Alfred Marshall, *Principle of Economics*, 8th edition, 1890)

13.1 INTRODUCTION

General cargo accounts for about 60% of the value of goods shipped by sea, so it deserves special attention.[1] Most of this cargo is transported by containerized liner services which provide fast, frequent and reliable transport for almost any cargo to almost any foreign destination at a predictable charge. Thus, a Californian wine grower selling 2,000 cases of wine to a UK wholesaler knows that he can ship the wine by a liner service; that the journey will take 12–15 days, and he is quoted a through rate for the container. On this basis he can work out his profit and his cashflow and make the necessary delivery arrangements with confidence. If the destination was not Europe, but Iceland, Kenya or India, the procedure would be much the same – he could ship his wine on a regular service at a fixed tariff that may increase with inflation but will not go through the wild peaks and troughs encountered in the charter market. It is an important business for the world economy as well as the shipping industry.

This chapter examines how the liner business operates. We start with a brief review of the evolution from cargo liners to containerized transport. This is followed by a discussion of the economics of liner pricing and costs which are central to managing the business. We then look at the demand for liner services and supply in terms of ships and business organization. Finally, we examine the major liner routes, ports and terminals. Some of the technical terms used in the liner business are listed in the Glossary.

13.2 THE ORIGINS OF THE LINER SERVICE

Liners are a comparatively recent addition to the shipping business and we reviewed their development in Chapter 1. From the 1870s improving steamship technology made it possible for shipowners to offer scheduled services. Until that time a few shipowners such as the Black Ball Line had tried to run regular services with sailing ships, but most general cargo was carried by 'tramp' ships working from port to port. Developments in the commercial world also made a contribution. Steamship agents became better organized, with branches at key trading points in the Far East. The banking services for day-to-day business were greatly improved and the extension of the telegraph to the Far East enabled trading houses in China to sell by telegraphic transfer in London and India.[2]

Steamships created the supply, the new commercial systems stimulated demand and the shipping community was quick to seize the opportunity. The opening of the Suez Canal in 1869 demonstrated the advantages of steamships, and when this was followed by a freight market boom in 1872–3 there was a flood of orders for steamships to set up liner services on the prosperous Far East route. Once established, the network of liner services grew rapidly into the comprehensive transport system which exists today.

The 'cargo liner' era

For a century until the 1960s liner companies ran fleets of multi-deck vessels known as *cargo liners*, versatile ships with their own cargo-handling gear (see Figure 1.9). Shipping had not subdivided into the many specialist operations we discussed in the previous two chapters and the liner services had to carry a mixture of manufactures, semi-manufactures, minor bulks and passengers. The trade routes were mainly between North America, the European countries and their colonies in Asia, Africa and South America, and on many of these routes trade was unbalanced with an outward trade of manufactures and a home trade of minor bulks. Filling the ship was the main aim and ship designers were preoccupied with building flexible vessels which could carry all sorts of cargo – even the first oil tankers built at this time were designed to carry a general cargo backhaul. The multi-deck 'cargo liner', with its capacity to carry both general cargo and bulks, was the preferred choice.

There was another aspect of the system which gave it great flexibility. Because the cargo liners were similar in size, design and speed to the 'tweendeckers used by tramp operators, the fleets were to a large extent interchangeable. A tramp could become a liner, and a liner could at times become a tramp.[3] This allowed liner companies to charter tramps to supplement their own fleets. For example, tramps returning from the UK to the River Plate to load grain would often carry a general cargo backhaul. Liner companies became charterers of tramp tonnage,[4] while tramp owners relied on the liner business as a cushion against the cycles in the bulk market and often built ships with 'tween decks and good speeds, which would fit conveniently into liner company schedules. Since the ships used in the bulk and liner markets were roughly the same size, this system of risk management worked well for both parties.

As trade grew in the twentieth century, the system was refined and developed. To improve productivity and widen their cargo base, liner companies built more sophisticated cargo liners, adding features such as tanks for vegetable oils, refrigerated holds, extensive cargo-handling gear, ro-ro decks and much automated equipment. They became increasingly complex and expensive. The *Pointe Sans Souci* class built in the early 1970s by Compagnie Générale Maritime (CGM) for their Europe-Caribbean service illustrates the extremes to which liner companies would go in their search for a more cost-effective cargo liner. These ships of 8,000 dwt were designed to carry cargo that had previously been carried by a mixed fleet of traditional liners and reefer ships. The forward holds were insulated to carry refrigerated cargoes, with collapsible container cell guides and electrical points for refrigerated containers. Doors for banana conveyors were let into the'tween decks in each hold and side doors allowed the'tween decks to be worked at the same time as the lower hold. Hatch covers were strengthened to take containers, and a 35-ton crane enabled the ship to be fully self-sufficient with container loads in the smaller ports of the West Indies. Holds aft of the bridge were devoted to palletized or vehicle cargo on two decks, with access by a wide stern ramp or a side door if the port did not have facilities for stern-to-quay loading. Below were tanks for carrying bulk rum.

Although the cargo liner was flexible, it was also labour- and capital-intensive. In the 1950s labour became more expensive and the trading world changed in a way which made flexibility less important than productivity. As the colonies gained independence the liner companies lost their privileged position in many of the core trades in which the cargo liners had been most effective. At the same time many of the minor bulk back-haul trades transferred to bulk carriers at rates the liners could not possibly match. As the bulk carrier fleet grew in size, the liner and bulk shipping industries grew apart. However, the most important change was in the pattern of trade. In the rapidly growing economy of the 1950s and 1960s, the real growth in trade was between the prosperous industrial centres of Europe, North America and Japan. Shippers in these trades needed fast, reliable, secure transport and the shortcomings of cargo liners became increasingly obvious. The cost, complexity and poor delivery performance of the cargo liner system became a major stumbling block. Shippers did not want to wait while their cargo made a leisurely progression round eight or ten ports, often arriving damaged, and shipowners found their expensive ships spending far too much time sitting in port.

For the liner companies, running cargo liners had become equally unrewarding. Expensive 'tailor made' ships spent up to 50% of their time in port, which tied up capital and limited the scope for economies of scale because doubling a cargo liner's capacity almost doubled its port time. There was not a great deal managers or naval architects could do to alleviate the fundamental problems of packing 10,000–15,000 tons of general cargo into a ship's hold.[5] By the 1960s the expense of the ships, the cargo-handling problems and the segregation of their cargo from the rest of the transport system had made the cargo liners technologically obsolete. This resulted in the complete restructuring of the shipping system which we discussed in Chapter 1 (see Figure 1.10) during which the liner and tramp system was replaced by the four business segments of bulk, specialized, containers and air freight.

The container system, 1966–2005

For the liner business the solution was to unitize general cargo using containers. Standardizing the cargo unit allowed liner companies to invest in mechanized systems and equipment which would automate the transport process and raise productivity. The whole procedure was essentially an extension of the production line technology which had been applied so successfully in manufacturing industry and bulk trades such as iron ore. The new system had three components. First, the product transported, general cargo, was packed in *standard units* that could be handled across the whole transport operation. Several other systems such as palletization and barges were considered, but containers were chosen by all the major operators. Second, investment was applied at each stage to produce an *integrated transport system* with vehicles at each stage in the transport chain built to handle the standardized units. On the sea leg the investment was in purpose-built cellular container ships. On land it required road and rail vehicles capable of carrying containers efficiently. Finally, the third step was to invest in high-speed *cargo-handling facilities* to transfer the container between one part of the transport system and another. Container terminals, inland distribution depots and container 'stuffing' facilities where part loads could be packed into containers all played a part in this process.

The deep sea containerization system we have today drew on the experience that already existed in the USA where, by the mid-1960s, there was a box fleet of 54,000 units (see Table 13.1).[6] It was pioneered by a US businessman with no shipping experience in the face of general scepticism from the liner industry. Malcolm McLean had spent his life building up McLean Trucking, a road transport company with a fleet of 1,700 vehicles. In 1955 he sold it for $6 million and bought the Pan Atlantic Tanker Company, which owned several T2 tankers.[7] One of these tankers, the 10-year-old *Poltero Hills* (which McLean renamed the *Ideal-X*) had a deck built of spars over the piping and manifolds and McLean had it fitted to carry sixty 35-foot containers. On 26 April 1956

Table 13.1 World container fleet, 1960–2005

Year-end	Container box fleet (TEU)	Container ship fleet (TEU capacity)	Containers (TEU) Per slot
1960*	18,000		
1965*	54,000	16,000	3.4
1970	500,000	140,500	3.6
1975	1,300,000	366,000	3.6
1980	3,150,000	727,600	4.3
1985	4,850,000	1,189,384	4.1
1990	6,365,000	1,765,868	3.6
1995	9,715,000	2,492,649	3.9
2000	14,850,000	4,812,286	3.1
2005	28,486,000	8,116,900	3.5

Sources: US Steel Commercial Research Division and CI Market Analysis, MTR (1976), Vol 6 Table 51, CRSL
*estimate

the *Ideal-X* loaded 58 containers in New Jersey, and sailed for Houston, the first seaborne shipment of modern containers (although there are many earlier cases of cargo being shipped in standard boxes). The boxes weathered the 3,000-mile journey and handling costs were 16 cents per ton, compared with $5.83 per tonne for break-bulk cargo handling so it was a commercial success.[8] A second tanker was converted and on 4 October, 1957 the maiden voyage of the first fully cellular vessel the 226 TEU *Gateway City,* from Newark to Miami was watched by a crowd of 400 (including New Jersey governor Robert B. Meyner, who helicoptered to the pier to deliver an address)[9]. When it docked in Miami its cargo was delivered to the consignee within 90 minutes.

The established liner companies remained sceptical. Even in 1963 Ocean Transport and Trading, the leading liner company of its day, was still doubtful about the new system, probably because initially they approached it as a development of their existing cargo liner operations and from this perspective the economics looked less attractive.[10] But given dedicated container-ships, terminals, truck distribution networks and a fleet of boxes, the analysis looked very different, though it is easy to understand why such a radical change must have been unwelcome to companies with large fleets of cargo liners. Many other less radical systems were investigated, including palletization, in which cargo was shipped on standard pallets in pallet-friendly ships, and deep sea ro-ro services which allowed a wide variety of cargo to be loaded on fork-lift trucks. However, the economics did not work in practice and deep-sea ro-ros remained a niche business (see Section 12.6 for a brief review of the trade today).

However McLean pressed on, renaming his company Sea-Land and in April 1966 *SS Fairland*, the first transatlantic container service, sailed from its newly constructed Port Elizabeth terminal in New Jersey to McLean's new trailer terminal in Rotterdam. The cargo arrived at its destination 4 weeks in advance of a conventional cargo liner service. The major European liner shipping companies were by this time busy setting up their own container services. Because of the size of the investment in ships, terminals and of course the containers, consortia were formed. For example, Overseas Containers Limited (OCL), a joint venture between P&O, Ocean Transport and Trading, British and Commonwealth and Furness Withy, was formed in 1965 and its first container service started on 6 March 1969. Subsequent events illustrate the corporate changes which occurred as the container industry grew over the next thirty years. In the early 1980s P&O gradually increased its share and in 1986 bought the remaining 53% to form P&O Containers Ltd (P&OCL), which merged with Nedlloyd in 1996 to form P&O Nedlloyd N.V. Ten years later in 2005 this company and was bought by the A.P. Møller-Maersk Group and incorporated into Maersk Line.

Developing the container service infrastructure

Developing a fleet of *container-ships* was a technical challenge because the structure, with its open hatches, was so different from the cargo liners shipyards were used to building. One of the earliest European orders by OCL, was for six 1600 TEU *Encounter Bay* class ships. They had open holds with cell guides so that the containers could be slotted in without clamping. Steel hatch covers fitted flush and provided a platform on which containers could be stacked four high and clamped in place. Although the ships were not big by the standards of tankers and bulk carriers, the open hold technology and cell guides were new and raised various technical problems. For the inland leg the investment in container-friendly trailers progressed rapidly and for their first service in April 1966 over 300 European truckers were signed up.[11]

The second vital component in the system was the *container terminal*. Previously liner ports had miles of wharves backing on to warehouses where ships would sit for weeks handling cargo. The container terminals were very different. Two or three berths, served by gantry cranes, backed on to open storage. To speed up the link with road transport Sea-Land stored the containers on trailers in a trailer park. Most other companies preferred to stack the containers three or four high, retrieving them from storage as required. Movement within the terminals was also mechanized, using fork-lift trucks, straddle carriers or, in a few cases, an automated gantry system. This system of cargo handling proved to be tremendously effective. Handling speeds vary from port to port, ranging from 15 to 30 lifts an hour, but averaging about 20 lifts per crane hour. The result was a dramatic improvement in productivity. Whereas general cargo berths typically handled 100,000–150,000 tons per year, the new container terminals were able to handle 1–2 million tons of cargo a year on each berth. Inter-modal compatibility was also greatly improved because the container itself is standardized. Forty years later in 2007 containers had taken over three-quarters of the general cargo trade and 4300 container-ships with a capacity of 10.6 million TEU were ferrying 35 million containers between 360 ports and carrying over 1 billion tons of cargo a year. Meanwhile Malcolm McLean had sold his share in Sea-Land for $160 million, so his pioneering efforts were well rewarded.[12]

Third, international agreement was needed on the sizes of *standard containers*. Because road regulations differed across the USA, various different sizes of container were in use, and McLean selected a 35 ft box for his first sea service because that was the best compromise. Eventually the ISO developed standards which applied to dimensions, corner casting strength, floor strength, racking tests and the gross weight of the container. Initially for general cargo the standard boxes were 8 ft high and 8 ft wide, with four optional lengths, 10 ft, 20 ft, 30 ft and 40 ft. In 1976, the height of standard containers was increased to 8 ft 6 ins, giving additional volume without altering the dimensions of the container. In recent years 20 ft and 40 ft containers have become the workhorses of the international container business. Out of a total container stock of 28.5 million TEU in 2004, 18 per cent were 20 ft units; 75 per cent were 40 ft units; 4 per cent were reefer containers and various specialized containers such as open top; and folding made up the balance (see Table 13.2). Containers generally have a life of 12–14 years. In Europe and the USA about half of the container fleet is leased.

Finally, the growth of the service depended on various technical developments which were taking place in the 1960s and 1970s. One was the communications and data processing revolution, discussed in Chapter 1. This made it possible to plan services, exchange detailed cargo manifests across the world and carry out the necessary paperwork in the much reduced time-scale required by containerization.

Table 13.2 World container stock by principal type

Container type 20-foot equivalent units ('000s)	1985	1995	2004	% in 2004
Standard	4,090	8,050	26,699	94%
of which				0%
20' 8'6"			5,060	18%
40' 8'6" (5.3 million units)			10,620	37%
40' 9'6" (5.2 million units)			10,362	36%
45' 8'6"			639	2%
Open-top	221	225	258	1%
Ventilated	46	89	26	0%
Folding flatrack	36	42	151	1%
Other	115	112	217	1%
Integral reefer	157	520	1,111	4%
Insulated reefer	77	72	24	0%
Tank	34	84	—	—
Total	4,776	9,194	28,486	100%

Source: *Containerisation International* 2005
World Container Census January 2005

The consequences of containerisation

Containerization was very successful in its main objective of reducing port time. A comparison of the operating performance of a *Priam* class cargo liner with the *Liverpool Bay* container-ship on comparable services published in 1985 illustrates the change. The 22,000 dwt cargo liner spent 149 days a year in port, 40% of its time. The 47,000 dwt containership reduced the port time to 64 days a year, just 17% of its time. As a result, a string of nine container-ships could do the work of 74 cargo liners.[13]

It also changed the way liner companies operated. First, and most importantly, unitization made 'door-to-door' service an essential part of the business. Previously most liner companies saw their responsibilities beginning and ending at the ship's rail, so the focus was on ships and shipping operations. The need to manage both the land and sea legs of the transport introduced logistics into the business, which in turn diluted the role of ships and changed the way companies approached pricing (see section 13.9). Second, the business consolidated into fewer companies. Hundreds of liner companies disappeared and liner shipping became the most concentrated sector of the shipping business. Third, the bustling ports of the cargo liner era disappeared, replaced by container terminals with few staff and fewer ships. Fourth, ships and shipowning slipped to the sidelines because the core business of liner companies was now through transport. Fifth, the tramp market for ships carrying containerizable cargoes disappeared. Container-ships could not switch between liner charters and bulk, so liner companies had to carry the marginal capacity they needed in their own fleets. Tramp operators turned to the bulk carrier or tanker markets. Sixth, minor bulk cargoes which had occupied the deep-well tanks, lower cargo holds and ro-ro decks of cargo liners moved into specialist vessels such as open hatch bulk carriers, parcel tankers, car carriers, MPP vessels and heavy lift ships (see Chapter 12).

Those were the effects on the shipping industry. But for the world economy the consequences were even more profound. Previously transport between regions had been slow, expensive and unreliable, with a high chance that delicate objects such as consumer electronics would be stolen or damaged during the lengthy process of loading and unloading a general cargo. Suddenly transport between regions became fast, secure and incredibly cheap. A few statistics put this into perspective. In 2004 packing 4,000 video-recorders into a 40 ft container reduced the freight cost from the Far East to Europe to around 83 cents per unit, whilst Scotch whisky could be shipped from Europe to Japan for 4.7 cents per bottle.[14] As a result, distance from the market and transport costs became a less important consideration in the location of manufacturing industry. As the container network grew in the 1980s and the 1990s, so did globalization.

13.3 ECONOMIC PRINCIPLES OF LINER OPERATION

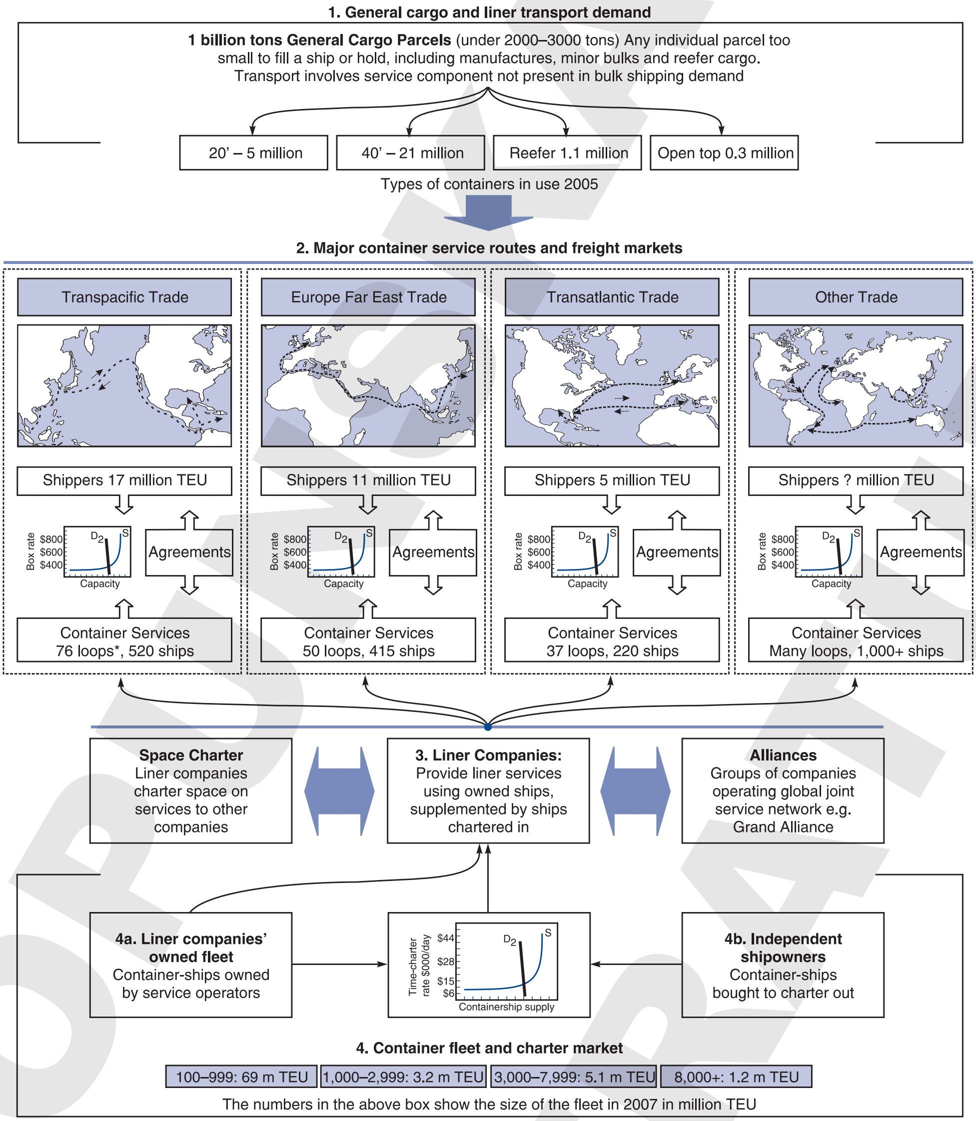
Now it is time to take a closer look at the economics of the liner business. We start with a strict definition:

> A liner service is a fleet of ships, with a common ownership or management, which provide a fixed service, at regular intervals, between named ports, and offer transport to any goods in the catchment area served by those ports and ready for transit by their sailing dates. A fixed itinerary, inclusion in a regular service, and the obligation to accept cargo from all comers and to sail, whether filled or not, on the date fixed by a published schedule are what distinguish the liner from the tramp.[15]

This definition focuses on the ships rather than the logistics, because the sea transport leg remains the core activity of a liner company, distinguishing it from freight forwarders and logistics companies which focus purely on the through-transport management, relying on others to transport the cargo.

By the end of the twentieth century container services had largely replaced the conventional cargo liner services, so it is the container market model which we are concerned with in this chapter. Before going into detail, it is helpful to see how the pieces in the liner transport system fit together and the diagram of the container market model in Figure 13.1 identifies four: the cargo, the services, the liner companies, and the fleet.

We start with cargo at the top of Figure 13.1. General cargo still generates the basic demand for liner services, just as it did for cargo liners previously, but containerization had two important consequences for transport demand, the first concerning economies of scale and the second product differentiation. First, the use of much bigger ships with improved cargo handling meant that small end bulk and specialized cargoes have



*A 'loop' is a round trip, usually with several calls on the outward voyage and several more on the return

Figure 13.1
The liner transport system, 2007
Source: Martin Stopford, 2007, Fleet Figures 1st Sept 2007 CRSL, Service figures NYK

increasingly become potential targets for containerization. Second, the containers may all look the same, but their contents still retain their demand characteristics. Packing chicken and chips and a gourmet meal in similar cardboard boxes does not make them identical products – gourmet customers expect home delivery (perhaps in a monogrammed van?), whereas the chicken and chips clients probably prefer take-away. Exactly the same is true for containerized cargo. High-value and urgent cargoes are likely to have a different demand profile from low-value minor bulk cargoes.

At the heart of the liner system are the major routes, which Figure 13.1 divides into four categories: the transpacific trade; the Far East to Europe trade; the transatlantic trade; and other trades which include the North–South trades and a mass of short-and medium-distance trades within Asia and elsewhere. In each case we have shippers with volumes of cargo to transport – 17 million TEU in 2004 crossed the Pacific, and 5 million TEU the Atlantic. All this cargo travels on container services provided by liner companies, and shippers have many to choose from. For example, on the transpacific trade there were 76 loops served by 520 ships in 2004. These loops offer many different arrival and departure dates, ports called at and through services offered, so it can be a bit of a jungle for the shipper. Like any other market, rates are negotiated between shippers and carriers (illustrated diagrammatically by the small graphs in Figure 13.1), but as discussed at the beginning of the chapter, there is a long history of container services cooperating to fix prices, or more recently to exchange information (illustrated by the 'agreements' arrows). The regulation of these trades has been a hot issue for at least 150 years that we will discuss later in this chapter.

The liner companies are shown in the lower middle of Figure 13.1. They provide the liner services and face the enormously complex task of deciding which ships will call at which ports and on which dates. In 2006 the biggest liner company, Maersk, had a 16% market share, but many of the companies with only 4–5% market share operated thirty or forty different services.

Finally, the container fleet and its charter market are dealt with at the foot of Figure 13.1. In July 2007 the container fleet was 4,200 ships, about the same as the tanker fleet, with another 1,300 on the order and the fleet had many different ship sizes within it. Economies of scale are a major issue that we will discuss in some detail. One of the key strategic decisions for a liner company is whether to purchase their own ships or to charter them. Until the beginning of the 1990s most of the fleet was owned by the liner companies, but as the decade progressed ownership of the fleet was gradually taken over by operators, often using German KG finance, which owned the ships and chartered them to service providers. By 2007 these independent operators owned almost half the fleet, one effect of which was to create the charter market shown at the bottom of Figure 13.1. This is a separate market with independent shipowners on one side and liner companies on the other, and it deals in ships rather than cargo transport. In the following four sections we will discuss each of these four segments of the liner business in more detail.

13.4 GENERAL CARGO AND LINER TRANSPORT DEMAND

General cargo and container movements

Between 1975 and 2007 the containerized cargo grew much faster than other parts of the shipping business. The number of containers lifted increased from 14.1 million TEU to 466 million TEU (Figure 13.2) and the average growth rate between 1990 and 2007 was 10.4% per annum. Analysing the trade presents many difficulties because anything that can physically go in a container is potential container cargo, and often other transport modes are competing for the same cargo. This means commodity analysis, even when it is possible for a few of the larger trades, does not tell the whole story and is not really practical. So we might as well accept at the outset that this is a highly complex business and analysts must expect problems getting to the bottom of it.

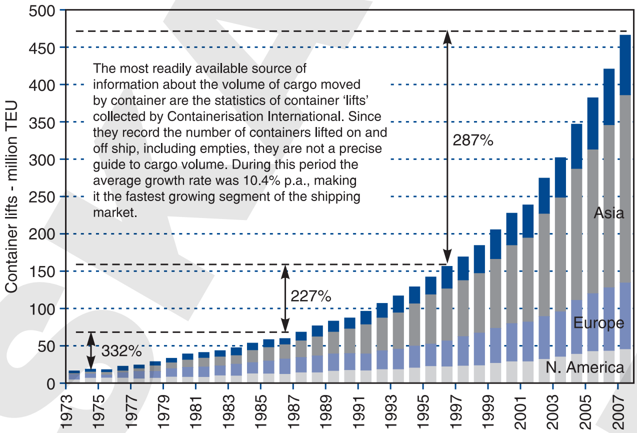


Figure 13.2
Liner trade, 1973–2007, and percentage growth per annum, 1981–2007
Source: Clarkson Research Services Ltd

A good starting point is the relationship between container cargo and world economic activity. Between 1983 and 2006 world GDP grew by 4.8% per annum and the value of manufactures exports grew by 6.6% per annum (Table 13.3), but container cargo grew much faster, averaging 10.1 per cent per annum for container lifts (column 4) and the volume of containerized cargo grew by 10.0 per cent (column 6). By 2005 the tonnage of containerized cargo had reached 1 billion tonnes[16] and the average tonnage per container lift in 2005 was only 2.7 tonnes per TEU, which reveals the underlying weakness of the container lift statistics as a measure of transport capacity. Container lifts include all container movements through ports, including double lifts when a container is trans-shipped from a deep-sea service to a feeder ship and containers returned empty on unbalanced trades. A 20 ft container can carry up to 24 tons, and 10 tons would be a more normal average.

Different shipping services compete for cargoes. Some cargoes, such as manufactured and semi-manufactured products, consumer goods, machinery, textiles, chemicals and vehicles have a very high value so they always travel by liner or possibly air freight which competes for the most urgent and high-value cargoes, especially on long routes. Clothing shipped from the Far East to Europe and electrical components are the sort of cargoes in this transport segment. Specialized shipping services are competitors for lower-value cargoes, including forest products, refrigerated cargo and wheeled cargo. The motor vehicle trade is a classic example, and the liner business lost most of the trade to specialized carriers using PCCs (see Chapter 12, page 494). At the other end of the scale, liner companies compete with bulk shipping for minor bulk cargoes such as steel products, building materials, foodstuffs such as coffee or empty gas canisters. Although these cargoes do not support high freight rates they provide what liner services used to call 'bottom cargo' which fills up the ship on routes where there is less cargo in one direction than the other. Whilst the core increase in container cargo volumes relies principally on the growth of the existing container cargo trades, especially the manufactured goods trade shown in Table 13.3, column 3, this is also topped up by the success

Table 13.3 The container and break-bulk trades, 1983–2006

	1	2	3	4	5	6	7	8	9	10	11
	World Economy % pa		Containerized cargo movements (moves)								
	GDP	manufactures	Container lifts		Container cargo		Tons	Break bulk	Dry bulk	Total dry cargo	
	%pa	exports (value)	TEU (m)	% pa	mt	%pa	per lift	mt	mt	mt	%pa
1983	6.3%	5.1%	46		127		2.8	487	1,254	1,868	
1984	7.0%	10.8%	53	17%	148	16%	2.8	511	1,396	2,055	10%
1985	4.0%	4.8%	57	7%	160	8%	2.8	549	1,461	2,170	6%
1986	6.8%	4.1%	62	9%	173	8%	2.8	555	1,415	2,143	–1%
1987	7.6%	6.3%	68	10%	192	11%	2.8	549	1,472	2,213	3%
1988	7.0%	9.5%	75	10%	211	10%	2.8	559	1,565	2,335	6%
1989	5.2%	7.8%	82	9%	231	10%	2.8	578	1,610	2,419	4%
1990	5.0%	6.1%	87	6%	246	6%	2.8	626	1,598	2,469	2%
1991	4.6%	3.6%	96	10%	268	9%	2.8	653	1,625	2,546	3%
1992	4.2%	4.7%	105	10%	292	9%	2.8	701	1,596	2,589	2%
1993	3.8%	4.1%	115	10%	322	10%	2.8	715	1,616	2,653	2%
1994	5.4%	11.1%	129	12%	357	11%	2.8	691	1,696	2,743	3%
1995	5.0%	9.0%	141	10%	389	9%	2.8	861	1,805	3,055	11%
1996	4.6%	5.3%	155	10%	430	11%	2.8	806	1,819	3,055	0%
1997	4.5%	11.0%	169	9%	470	9%	2.8	872	1,916	3,258	7%
1998	0.2%	4.8%	183	8%	503	7%	2.8	859	1,900	3,262	0%
1999	5.5%	5.1%	205	12%	560	11%	2.7	877	1,896	3,334	2%
2000	5.8%	13.0%	227	11%	628	12%	2.8	929	2,042	3,598	8%
2001	1.1%	–1.4%	239	5%	647	3%	2.7	910	2,095	3,652	1%
2002	3.3%	4.0%	275	15%	718	11%	2.6	961	2,172	3,851	5%
2003	2.6%	4.9%	303	10%	806	12%	2.7	955	2,291	4,052	5%
2004	5.3%	10.0%	343	13%	919	14%	2.7	926	2,469	4,313	6%
2005	4.9%	6.0%	381	11%	1,017	11%	2.7	920	2,564	4,502	4%
2006	5.4%	8.0%	419	10%	1,134	11%	2.7	882	2,703	4,719	5%
Av. '83–'06	4.8%	6.6%		10.1%		10.0%		2.6%	3.4%		4.1%

Notes
Col 2: manufactures exports show % change at constant prices; source World Bank
Col 3/4: shows container lifts, including empties
Col 5/6: shows container cargo moved in the year (estimate – the actual amount is not known)
Col 7: col 3 divided by col 5. 20' containers usually carry 10–12 tons, so there are many unexplained lifts
Col 8: break bulk cargo is the residual after deducting containerized cargo and bulk from col 10
Col 9: dry bulk commodities like ore, coal, grain etc.
Source: Cols 1 & 2 World Bank; cols 3–11 Clarksons SRO (spring 2006)

of liner operators in both generating new cargoes and winning cargo from the bulk and specialized segments.

The characteristics of containerized cargo

As a practical example of the range of containerized cargoes, exports by commodity from the Port of Vancouver are shown in Table 13.4. The import trade includes all sorts of manufactured commodities, including consumer product, textiles, furniture, car parts, iron and steel, toys and a larger group of 'others' which are unidentified. This is typical of the import profile of a mature industrial economy. The exports have a very different character. Canada is a resource-rich country and exports many primary commodities – wood

Table 13.4 Port of Vancouver trade

13.4.1 Principal containerized commodities inbound

Commodity ('000 metric tonnes)	2003	2004	2005	Increase 2004–5
A. Containerized commodities inbound				
Misc. consumer products	586	605	687	14%
Home & bldg products	419	506	620	23%
Furniture	440	489	543	11%
Industrial machines/parts	457	472	538	14%
Textile/clothing	449	470	536	14%
Misc. industrial products	239	312	338	8%
Autos/auto parts	287	311	312	0%
Consumer electronics	284	293	307	5%
Iron/steel	196	247	231	–6%
Toys/sports equipment	198	200	205	2%
Others	1,419	1,496	1,675	12%
Total	4,974	5,401	5,992	11%
B. Container movements ('000 TEU)				
Loaded with cargo	713	783	857	9%
Empty containers	35	42	27	–36%
Total	748	825	884	7%
Tons cargo per loaded TEU	7.0	6.9	7.0	1%

13.4.2 Principal containerized commodities outbound

Commodity ('000 metric tonnes)	2003	2004	2005	Increase 2004–5
A. Containerized commodities outbound				
Wood pulp	1,646	1,966	1,840	–6%
Lumber	1,348	1,550	1,272	–18%
Peas/beans/lentils	448	427	524	23%
Waste paper	408	376	510	36%
Hay/alfalfa	241	356	401	13%
Fresh/frozen pork	313	351	382	9%
Soya beans	214	337	357	6%
Malt	173	287	264	–8%
Newsprint	209	244	245	0%
Scrap metal	193	231	229	–1%
Others	2,449	2,534	2,383	–6%
Total	7,642	8,659	8,407	–3%
B. Container movements (000 TEU)				
Loaded with cargo	577	695	708	2%
Empty containers	214	145	175	21%
Outbound containers (000 TEU)	791	840	883	5%
Tons cargo per TEU	13.3	12.5	11.9	–5%

Source: Port of Vancouver

pulp, lumber, soya beans, newsprint, scrap metal, and again a very large volume of unidentified commodities. Although these are low-value commodities, container-ships with plenty of spare capacity on the return leg to the Far East may well be prepared to heavily discount box rates. Finally, the growth rates of the different commodities vary considerably. For example home and building products grew by 23% per annum in 2005; auto parts imports were static; and toys grew by only 2%. Exports were equally variable – wastepaper declined in 2004, and then grew by 36% in 2005, whilst malt grew at over 50% in 2004 and declined by 8% in 2005. All of which leaves no doubt about the variability of this business and the wide range of cargoes transported.

The weight of the containers varies, depending on the contents. In 2005 Vancouver's average outbound container carried 11.9 tons of cargo, whilst the average inbound container carried 7 tons, reflecting the different characteristics of the inbound and outbound trades. The contents also vary in value. Electronic goods such as TV sets are worth over $30,000 per tonne, motorcycles $22,000 per tonne, basic clothing such as jeans $16,000 per tonne, and designer clothing perhaps $60,000 per tonne. At the other end of the scale, many of the export commodities are worth less than $1,000 per tonne, for example scrap metal $300 per tonne and steel products $600 per tonne. These differences are important because they affect transport pricing.

From an economic viewpoint, the general cargo trade, whether in boxes or break bulk, has two important differences from the bulk and specialized cargoes discussed in the previous chapters: first, transporting many small parcels requires a larger and more expensive administrative fixed cost; and second, the obligation to sail to a timetable makes capacity inflexible. This indivisibility arises because capacity expands in ship-sized increments, so when trade is growing, new ships must be ordered in multiples dictated by the service frequency, with sufficient capacity to cater for future growth. These are apparently small points which make a tremendous difference to the business model. Whereas the bulk market can respond to supply–demand imbalances by moving their least efficient ships into lay-up, liner companies must stick with their schedules. If it takes six ships to run a weekly service, they must operate six ships. From the outset this has created problems for liner operators, making capacity management a key feature of the business. The emergence of the two supporting markets shown in Figure 13.1, for container-ships and slot capacity, has helped to resolve this problem by introducing flexibility.

In addition to the usual trade cycles which affect all shipping business, there are two reasons why capacity management can be a problem. *Seasonality* occurs on many liner routes where cargo volume is higher at some times of the year than others. *Cargo imbalances* occur when there is more trade in one direction than the other, forcing ships to sail part loaded on the leg with the smaller trade flow. Both problems also occur in the bulk market, but they are quickly resolved by market forces as shipowners negotiate rates and move from trade to trade. Liner companies lack this flexibility. With so many customers it is not practical to negotiate a rate for every cargo. This combination of fixed prices and inflexible capacity leaves liner companies with a pricing problem which has dominated the industry since it started.

Price, service and the demand for liner transport

Pricing is a central issue for liner service operators and we need to be aware of the total transport cost. Sea freight is only one part of the total cost invoiced to the shipper, which also includes inland transport costs at the origin and destination terminal service charges. The example in Table 13.5 shows that the terminal and inland transport costs can account for as much as the sea freight. In addition, surcharges such as currency adjustment factors) and (interim fuel participation also called bunker surcharges) may be a part of the freight costs, depending on whether a surcharge is in effect or not.

Table 13.5 Example of container transport costs UK to Canada ($ per container)

	20′	40′
Inland charges (origin)	225	225
Terminal charges (origin)	248	340
Ocean freight	700	1100
Terminal charges (destination)	121	121
Inland charges (destination)	225	300
Total	1519	2086

Source: Canada-UK Freight Conference

The price that a shipper is prepared to pay depends to some extent on what is in the container. Although containers are physically homogeneous, their contents are not and have different characteristics in terms of price elasticity and service requirements. Shippers of high-value commodities are likely to be willing to pay more whilst for lower-value commodities, where the transport cost is a significant part of the delivered price, pricing is crucial. For example, a company distributing large tonnages of low-value cellophane rolls to processing plants in Europe might take the view that as long as they have a reasonable tonnage in the pipeline at any one time, considerations of service and claims experience are of far less importance than rate per ton.[17] For this type of commodity, prices are subject to intense competition and liner companies often discount heavily to win the business, especially where they have spare capacity on one leg of the voyage. Some examples of the price-sensitive cargoes that are containerized are as follows:

- *Wool*. A high proportion of the wool trade is containerized. Wool is 'dumped' (i.e. compressed) into bales which are packed into 20 ft containers, giving an average container weight of 18 tons.
- *Cotton*. US West Coast cotton exports are now containerized. A total of 82 standard dumped bales can be packed into a 40 ft container.
- *Wine*. This is shipped by container either in cases or in 5,000-gallon bulk container tanks. A 40 ft container can hold 972 cases of 1 litre bottles and 1,200 cases of 750 millilitre bottles.
- *Rubber*. This used to be shipped in bales. To facilitate containerization, some companies have now adopted standard bale sizes and pack the bales in shrinkfilm rather than timber crates. Latex is shipped in drums packed in containers.

However, for many cargoes, particularly those of high value, the shippers have more to lose if the service is poor than they could possibly gain from squeezing the price down a few per cent. For example a motor cycle manufacturer exporting components world-wide must be able to meet delivery schedules to its dealer network. Frequent services, sufficient volume of available shipping space, reliable advance information about vessel arrival and departure times, speed, and responsible management of cargo landed at the destination are all of crucial importance to a company distributing its products over a long distance. For example, a study comparing air and sea freight for the USA's merchandise trade concluded that each day saved is worth 0.8% of the ad-valorem for manufactured goods.[18] For a $30,000 per tonne container cargo that is a saving of $240 per tonne, a sizable sum of money. Whilst this sort of analysis must be applied with care, it does suggest that speed has a value to shippers of high-value commodities.

For this reason service requirements now dominate the liner business. Over the last 30 years international businesses have systematically tightened the management of product flows and inventory costs, often using 'just in time' control systems. Containerization played a major part in this process by allowing companies to access global markets through a fast, reliable transport network. Operating alongside the established freight forwarders, a new generation of logistics providers emerged. A good example of why customers are willing to pay extra for speed and reliability is illustrated by a freight forwarder dealing with the motor trade:

> We are heavily involved in spare parts traffic for the motor industry where in recent years inventory stocks have been reduced to the absolute minimum. This obviously has given quite substantial cost savings to importers and exporters. But they are prepared to spend some of this cost saving in additional freighting charges to ensure that their production lines are kept moving.[19]

Liners are part of a supply system and customers view the cost and benefits of transport in the context of the business as a whole.

Product differentiation – the conflict of volume versus speed

It follows that there are two basic models of liner shipping. One is the low cost option and the other is where containers are treated as part of a package of services.[20] The challenge for liner companies operating under the second model is to find some way of differentiating their product that will support premium pricing. One method of doing this used by international businesses is to differentiate the products they offer to different market segments. For example, within a couple of years of Ford launching the Model T, Alfred Sloan of General Motors had used market segmentation to push Ford aside. He split his product range into five segments, with Cadillac at the top and Chevrolet at the bottom. It was an immediate success and car manufacturers still follow the same strategy. Similarly, passenger airlines segment their market by putting premium passengers at the front of the plane and calling it 'Business Class' and charging more for flexible tickets.

An example in the transport business is the parcel post market. In the 1970s FedEx segmented the parcel market by taking away the delivery of urgent and high-value merchandise from the US Postal Service which, preoccupied with the rapid growth of volume, had overlooked what seemed to be a minor niche.[21] At the time the big air freight operators like Pan Am were also convinced that shippers wanted cheaper transport using big cargo planes or traditional trucking lines such as UPS. The founder of FedEx, Fred Smith, studied each step in the collecting, transporting and delivering of packages and in billing for the work, and decided there was a market for a premium parcel service offering guaranteed fast delivery. He used small business jets that, although expensive, allowed FedEx to offer frequent services to smaller airports closer to the customer, without the big loads needed to fill the larger planes, thus demonstrating that market segmentation can be made to work in transport.[22]

The same issues of service differentiation are present in the liner shipping market and container transport can be viewed as a package of services which is likely to include the following seven characteristics:

- *Vessel on-time arrival*. On deep-sea routes the liner service is the customer's only direct link to his export market. Some customers are likely to value reliability of service. In terms of the transport service, adherence to fixed day schedules and on-time pick-up and delivery are important. The management of feeder services where these occur is also important.
- *Transit time door-to-door*. On long voyages, particularly for high-value products, speed of transit may be a major consideration owing to the cost of inventory. In this context, air freight may be a significant competitor, particularly where a shipping time of 4 weeks is involved in a Far East to Europe voyage.
- *Carrier cost per move*. The charge for transporting the container from origin to destination, including additionals.
- *Cargo tracking*. The ability of the shipper to check the progress of his cargo
- *Frequency of sailings*. Sea transport is one stage in the overall production process. Frequent sailings offer the manufacturer the opportunity to service one-off orders rapidly and enable him to reduce the level of stocks held at each end of the transport operation.
- *Reliability of administration*. Customers value prompt and accurate administration. The ability to provide timely quotations, accurate bills of lading, prompt arrival notices, accurate invoices and to resolve problems when they arise all play a part in the customer's evaluation of the liner company's performance.
- *Space availability*. The ability of the service to accept cargo, even at short notice, may be valued by businesses that are not able to plan their transport requirements far in advance.

A survey by the US Department of Transportation Marine Administration of companies serving the US liner trades in 2004 identified on-time arrival, cargo on-time delivery and cost reduction as the three areas which receive the greatest emphasis.[23] In practice, most shippers look for a combination of the above factors, though research suggests that there is no clear pattern of preferences which applies to all shippers and surveys of shippers' attitudes produce widely differing results. A survey of 50 shippers in the US domestic trades found that timeliness of service was the most important single factor,[24] but another study of the attitudes of shippers in North America and Europe found that cost of service and problem-solving capability were ranked most highly. Transit time, which had been placed third in an earlier survey carried out in 1982, had fallen to seventh place a decade later, suggesting that priorities change.[25] Common sense suggests that this must be the case. Price will only be a significant decision variable if different prices are quoted by different companies. More fundamentally, different shippers have different priorities, depending on the cargo and the nature of their business.

The practical difficulties of achieving these service levels are considerable. For example a survey of timekeeping of services in North America and the Far East found that in North America three-quarters of the vessels tracked arrived on or one day after their scheduled time. In the Far East ports 89% of the vessels arrived within a day of schedule.[26] At first sight it might seem surprising that timekeeping presents such a problem. However, liners work in such diverse conditions that it is difficult to plan for every contingency. Some delays are caused by breakdowns such as engine failure or dry dockings that overrun. Then there are accidents (e.g. collisions), natural disasters such as earthquakes, adverse weather, and congestion. Many of these are avoidable at a price. In the long-term powerful ships which can make up lost time and realistic schedules which incorporate a margin for delays are the solution. In the short term skipping ports is a common way of catching up on schedule, or for serious delays chartering a replacement ship, if one is available.

Two central issues for liner companies are whether customers will pay a premium for better service and how providing the higher service levels fits with the needs of the other market segments, in particular the low-value, high-volume cargoes. In theory high-value commodities should support premium freights but it is a complex issue. One ocean carrier summed up the problem in the following terms:

> We submit our rates (to the shipper) as required but often have no way of knowing if service profiles are also taken into account. Sometimes we don't even know the people we are addressing … Some global shippers claim that liner shipping is just a commodity as when a container is booked with any carrier, it is likely to be shipped on the same vessel as other carriers, from the same container terminal, in the same type of container from the same leasing company, and to the same container terminal at the port of discharge.[27]

Containerizing minor bulk cargoes

Minor bulk commodities such as forest products, steel products, minor ores, soya beans, scrap metal and cotton are all potential cargoes for containerization, but each presents its own difficulties. This is a very different business. The low unit costs required to compete in these trades call for bigger ships which in turn need bigger arterial hubs. Inevitably this slows the transit times, especially for the unfortunate customers at the extremities of the feeder network. That is fine for the lower-value cargoes, but may not suit the shippers of premium cargoes who need speed and certainty. From the service operator's point of view it can be a slippery slope, putting container-ship operators on the same 'bottom cargo' treadmill that was such a problem for liner operators before containerization. The economic benefits of very big ships are surprisingly slim, and because ship-related costs can be less than a quarter of the total service cost, the financial benefits of size diminish as ships get bigger. We will develop this point in Section 13.8 below.

Despite these drawbacks, containerization of minor bulk cargoes plays an important part in helping service operators to obtain a balanced cargo payload, and new types of containers have been developed to allow the transportation of *low-value* or non-standard cargoes. The main types were summarized in Table 13.2. Open-top containers are used for heavy lift; reefer and ventilated containers are used for frozen and chilled cargo and various perishable agricultural crops; flat racks (a flatrack container has a load platform with a bulkhead at either end) are used for awkward cargoes; and tank containers are used for various bulk liquids such as wine and chemicals.

Containerizing cargoes not previously carried often involves research into packing, stowage and handling methods. For this reason the speed with which containerization has penetrated some trades, particularly the minor bulks, depends upon finding practical ways to allow difficult cargoes to be containerized. Sometimes the problem is the delicate nature of the cargo. For example, confectionery exports from the UK are containerized using insulated containers which need special handling to avoid condensation and tainting from previous cargoes.[28] Or it might be a matter of finding a way to reduce the cost by more effective stowage. Most of the motor cycle export trade from Japan is now containerized. By careful planning and some disassembly, a total of 28 large motor cycles or up to 200 small ones can be packed into a 40 ft container. This emphasis on efficient stowage led some manufacturers to take container dimensions into account in their design. However, the trend is not always towards packing more cargo into a container. In the integrated transport business, what matters is the total cost. High-density stowage which calls for some assembly at the destination can be expensive and difficult to control. As transport costs have fallen and labour costs have increased, many manufacturers have reverted to shipping motor cycles fully assembled and carefully packed.

An example of the practicalities of containerizing delicate cargoes is provided by the export of bulk coffee from Brazil to the USA.[29] Traditionally coffee beans were shipped in 60 kg bags, loaded into the hold of a general cargo ship. When containerization was introduced, the bags were packed into a container. Problems with condensation were overcome by using 'dry bags' which absorbed the moisture released by the coffee beans and a massive improvement in efficiency was achieved. Instead of having to individually handle about 250 sacks, the single container is dropped into place in the container-ship, an operation taking about 1½ minutes in a purpose-built container vessel. Then in the mid-1980s importers started looking for ways to reduce the labour required to 'stuff' and 'unstuff' containers with 60 kg bags. Eventually they developed a new cargo-handling system which loaded the container by gravity feed and discharged by a special chute, taking only a few minutes, compared with several hours and much more labour for manual handling. This example illustrates the important point that containerization does not just save transport costs. It has an impact on packaging costs and cargo-handling costs at either end of the cargo leg.

Finally, there is *project cargo*. Some specific items shipped by liners include, for example, equipment for two cement plants, electrification projects for Singapore and Korea, a water filtration plant for Hong Kong, a textile fibre plant for the Philippines, a telecommunications project for Malaysia and equipment for a mass transit railway system in Hong Kong. These cargoes can only be stowed on deck by container-ships and are generally transported by the MPP and heavy lift fleets discussed in Chapter 12.

13.5 THE LINER SHIPPING ROUTES

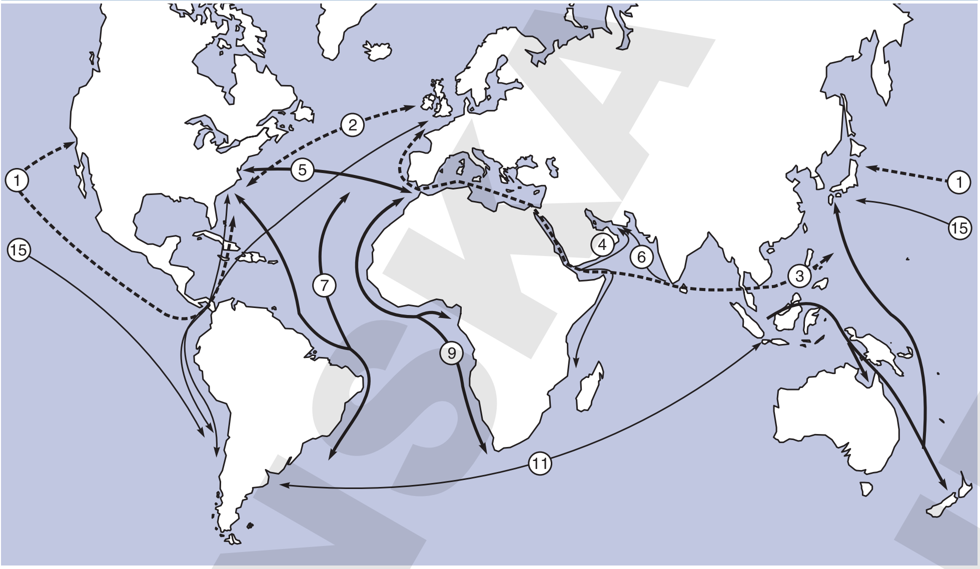
Providing liner services that cover the globe is a daunting task. In its annual *Maritime Transport Study* the United Nations identified 32 maritime coastal regions. There are 1024 potential liner routes between these areas, and some of the coastal regions cover thousands of miles of coastline with many ports. The task of the liner market is to sort out a route network which cost-effectively meets the changing needs of the shippers in these coastal regions.

The industry generally divides the trade routes into three groups, shown in Table 13.6. Firstly, there are the East–West trades. These include the prominent long-haul routes which use the biggest container-ships, account for almost half the containerized cargo and link the industrial centres of North America, western Europe and Asia. Secondly, there is a bewildering array of North–South services linking the economies of the Northern and Southern hemispheres and accounting for almost a quarter of the trade. They also fill the gaps where cargo volumes are lower, for example between South America and Australasia. Thirdly, there is the intraregional cargo, which is shorter-haul and uses smaller ships. It accounts for a third of the cargo volume in Table 13.6, but much less in terms of ship demand because the voyages are generally much shorter. This division of the liner trades is convenient, but in reality the global liner network is constantly adjusting to the changing needs of the world economy and if the network of routes fell into neat categories, the liner companies would not be doing their job properly. So we cannot define the routes precisely, but with this qualification the groupings in Table 13.6 provide a convenient framework for discussing the broad shape of the transport system.

The East–West trades

By far the largest volume of trade is on the East–West routes. These trades dominate the liner business. Over the last 20 years they have grown enormously, underpinning the rapidly expanding trade links between these areas. These routes probably provide employment for over half of the container-ship capacity and provide the main employment for ships over 4,000 TEU.

Table 13.6 Principal world container routes, 2004, showing approximate trade volumes



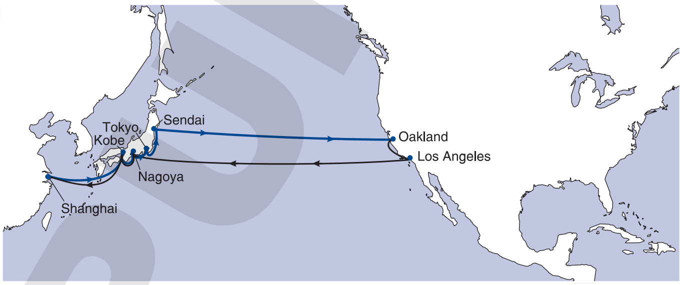
	Route no	1994 '000 TEU p.a.	1994 % total	2004 '000 TEU p.a.	2004 '000 TEU p.a.	2004 Total trade	2004 % total
1. East–West trades				*East*	*West*		
Transpacific	1	7,470	20%	11,361	4,892	16,253	17%
Transatlantic	2	3,030	8%	2,473	3,228	5,701	6%
Europe–Far East	3	4,895	13%	3,538	7,510	11,048	12%
Europe–Mid East	4	645	2%	1,675	525	2,200	2%
NorthAmerica–Mid East	5	205	1%	160	287	447	0%
Far East–Mid East	6	255	1%	300	1,300	1,600	2%
Total		16,500	44%	19,507	17,742	37,249	39%
2. North–South trades				*North bound*	*South bound*	*Total trade*	
Europe to							
Latin America	7	1,150	3%	2,046	799	2,845	3%
South Asia	8	475	1%	910	600	1,510	2%
Africa	9	950	3%	770	1,487	2,257	2%
Australasia	10	400	1%	256	343	599	1%
Total		2,975	8%	3,982	3,229	7,211	8%
North America to							
Latin America	11	2,000	5%	2,627	1,526	4,153	4%
South Asia	12	250	1%	533	216	749	1%
Africa	13	100	0%	149	189	338	0%
Australasia	14	275	1%	203	252	455	0%
Total		2,625	7%	3,512	2,183	5,695	6%
Far East to							
Latin America	15	725	2%	1,100	850	1,950	2%
South Asia	16	425	1%	850	1,120	1,970	2%
Africa	17	425	1%	825	975	1,800	2%
Australasia	18	875	2%	785	800	1,585	2%
Total		2,450	7%	3,560	3,745	7,305	8%
Total North–South Trades		8,050	22%	11,054	9,157	20,211	21%
3. Intra-regional							
Asia	19	6,750	18%			28,154	29%
Europe	20	4,250	11%			7,675	8%
North America	21	1,250	3%			339	0%
Total intra regional		12,250	33%			36,168	38%
Other	22	300	1%			1,957	2%
Total container trade		37,100	100%			95,585	100%

Source: Clarkson Research and various sources

THE TRANSPACIFIC TRADE

Containerization started in the Far East trade in December 1968 when Sea-Land introduced the container service from Seattle to Yokohama and the Japanese shipping companies introduced six 700/800 TEU container ships into a service between California and Japan. Now the biggest deep-sea liner route is the transpacific trade between North America and the Far East, with 16 million TEU of trade, representing 17% of the world total. The services operate between North American ports on the East Coast, the Gulf and the West Coast, to the industrial centres of Japan and the Far East, with some services extending to the Middle East. Some services to the USA Atlantic coast operate direct by water through the Panama Canal, but other containers to US East Coast are shipped under one bill of lading to a US West Coast port and then by rail to the East Coast destination, thus avoiding the Panama transit. On the rail leg containers may be double-stacked. There is a substantial cargo imbalance on this trade, and in 2004 eastbound exports from the 10 major Asian economies[30] to the USA were 11.4 million TEU, whilst the westbound exports were only 4.9 million TEU. This creates significant opportunities for westbound minor bulk cargoes of the sort we saw in the Port of Vancouver trade data in Table 13.4.

In 2004, about 18 operators were servicing the trade, including Maersk, Evergreen, CMA, Mediterranean Shipping Company (MSC), the Grand Alliance and the New World Alliance. An example of a round voyage is provided in Figure 13.3. The service calls at five ports in South East Asia and two on the US West Coast, covering about 16,500 miles. At a speed of 21.5 knots the sea time is 27 days, with an additional 8 days in port, giving a round journey time of 35 days. Port-to-port delivery times range from 10 to 18 days, depending on where the ports lie in the schedule. To provide weekly 'express' sailings in this trade requires a fleet of five ships, though some services might increase the



Load	Discharge	Distance*	Sea days	Port days	Total
Sendai	Oakland	4,800	9.3	1	10.3
Oakland	Long Beach	450	0.9	1	1.9
Long Beach	Oakland	450	0.9	1	1.9
Oakland	Nagoya	4,800	9.3	1	10.3
Nagoya	Kobe	450	0.9	0.5	1.4
Kobe	Shanghai	783	1.5	0.5	2.0
Shanghai	Kobe	783	1.5	1	2.5
Kobe	Nagoya	450	0.9	0.5	1.4
Nagoya	Tokyo	400	0.8	0.5	1.3
Tokyo	Sendai	600	1.2	1	2.2
Total		13,966	27.1	8.0	35.1

Av. speed (knots) 21.5 *distance in nautical miles

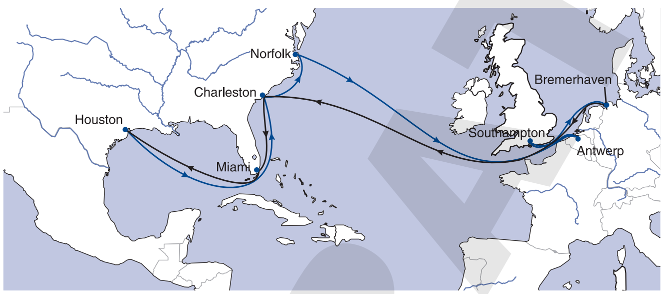
Figure 13.3
Typical transpacific loop using five ships

number of port calls so as to operate to a six-week round voyage which can be operated by six ships. The 'all water' services to the US East Coast continue on through the Panama Canal, adding another 5,000 miles and requiring nine vessels, and delivery times are very wide, ranging from 10 to 36 days at the extreme ends of the service. Because of the long voyage time the transpacific trade uses the biggest ships, with many 'post-Panamax' vessels over 4,000 TEU on this service, though the East Coast services are limited to Panamax vessels.

THE NORTH ATLANTIC TRADE

The North Atlantic was the first route containerized in the mid-1960s, as one might expect, since at that time it linked the two major industrial centres of the world, East Coast North America and western Europe. In 2004 it had a trade of 5.7 million TEU, accounting for 6% of world container trade (Table 13.6). There is a trade imbalance westbound, reflecting the greater volume of cargo to North America. In 2004, for example, there was 3.2 million TEU of cargo travelling west between Europe and the USA and only 2.5 million TEU in the opposite direction.

Geographically, the North Atlantic trade covers the major European ports of Göteburg, Hamburg, Bremerhaven, Antwerp, Rotterdam, Felixstowe and Le Havre, though there are some other smaller ports included on the itineraries of certain liner companies. At the North American end of the operation it is organized into two sections covering northern Europe to US Atlantic and northern Europe to the St Lawrence. The principal Canadian ports serviced are Montreal and Halifax, while in the US Boston, New York, Philadelphia, Baltimore, Hampton Roads, Wilmington and Charleston are all regular port calls. Some services extend into the US Gulf, particularly to Houston and Mobile. A typical service is shown in Figure 13.4. It calls at three ports in Europe and



US Gulf to Europe Service:

Transport time between ports in days

From/To	Antwerp	Southampton	Bremerhaven
Miami	18	19	21
Houston	15	16	18
Charieston	11	12	14
Norfolk	9	10	12

Europe to US Gulf Service:

Transport time between ports in days

From/To	Charleston	Miami	Houston	Norfolk
Bremerhaven	10	12	15	21
Southampton	12	14	17	23
Antwerp	13	15	18	24

Figure 13.4
Typical transatlantic loop using five ships

four in the USA. The round voyage distance is about 8,000 miles, which can be completed in 18 days at a speed of 19 knots. Allowing 7 days for port time and a sea margin of 2 days, the round trip takes about 28 days, which could be serviced using a fleet of four ships.

There were 25 carriers operating 37 service loops in 2004 employing 220 ships, an average of six ships per loop. The current conference, the Trans Atlantic Conference Agreement (TACA) operates between US ports, including the Gulf and Pacific, and northern Europe, including the UK and Ireland, Scandinavia and Baltic ports. In 2004 the TACA members provided 11 service strings covering 16 ports in Europe and 13 in the United States. Anyone can join this conference and there are no trade shares.

WESTERN EUROPE TO THE FAR EAST TRADE

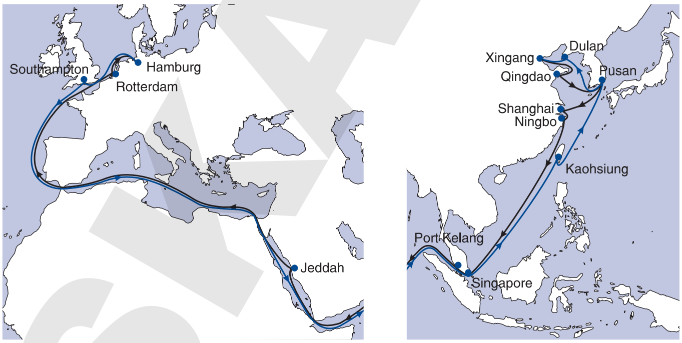
This route covers the trade of northern Europe, stretching from Sweden down to St Nazaire in France, to the Far East, an enormous maritime area covering West Malaysia, Singapore, Thailand, Hong Kong, Philippines, Taiwan, South Korea, China and Japan. This was one of the first trades to be covered by a conference system, the Far East Freight Conference (FEFC), and in 2004 there were about 13 operators or consortia running about 400 ships on many different loops.

Three major operators in the Far East trade are the Grand Alliance, composed of NYK, Neptune Orient Lines and Hapag-Lloyd; the Global Alliance, consisting of MOL, OOCL, APL and MISC; and Maersk. The round-voyage time is over 60 days, requiring nine ships to provide a weekly sailing covering a full range of Asian ports, though a shorter service schedule using eight ships and fewer portcalls is often used. The major operators run separate weekly services direct to Japan and Korea, and to South East Asia. It is the large number of ships required to operate a regular service in this trade that necessitated the development of consortia. A typical round voyage (Figure 13.5) would involve calling at three European ports (e.g. Rotterdam, Southampton, and Hamburg), Singapore and eight or nine ports in South East Asia. The permutations are enormous, involving the option to stop off in the Middle East and the choice of which countries to visit in Asia.

ROUND-THE-WORLD SERVICES

A seemingly logical development was to fuse these three main liner routes into a single global service. In the early 1980s several operators took this step, of which the most important were Evergreen and United States Lines. Evergreen set up a service with 12 vessels in each direction around the world with a round trip of 80 days, providing a 10-day service frequency in each direction. This service was initially introduced with eight ships in September 1984, but it rapidly became apparent that the 10-day service compared unfavourably with the seven-day service operated by competitors, particularly on the North Atlantic. As a result, in 1985 the number of ships was increased to 11 in each direction, and then to 12, giving a weekly service with a round trip time of 77 days. The ships used on the service were G-class vessels of 2700 TEU which were then lengthened to 3428 TEU. Going westbound, after calling at the UK and north continent ports, vessels proceeded down the East Coast of North America through the Panama Canal to the US West Coast, Japan, the Far East and through the Suez Canal to the Mediterranean.

For some years DSR-Senator and Cho Yang ran a round-the-world service, but with the notable exception of Evergreen this method of operation attracted few operators and in the 1990s it became clear that the round-the-world service strategy faced two fundamental problems. First, the need to link services reduced flexibility over port calls, and balancing calls on the three routes added complexity. Second, the ships used on the arterial trades increased in size and the ships which could transit the Panama Canal became uncompetitive. The second problem will be removed when the development of the Panama Canal to handle bigger container-ships is completed.



Transport time between ports in days

From/To	Rotterdam	Hamburg	Southampton
Jeddah	8	11	14
Port Kelang	15	18	21
Singapore	16	19	22
Ningbo	22	25	28
Shanghai	22	25	28
Pusan	24	27	30
Qingdao	27	30	33
Xingang	29	32	35
Dalian	30	33	36

Figure 13.5
Service loop to Europe from Far East trade

The North–South liner routes

The North–South liner services cover the trade between the industrial centres of Europe, North America and the Far East and the developing countries of Latin America, Africa, Far East and Australasia. There is also an extensive network of services between the smaller economies, especially those in the Southern Hemisphere. These trades, which are listed in Table 13.6, have a very different character. Cargo volumes are much lower, with the many routes together accounting for only 21% of the container cargo volume in 2004. However, this understates the importance of these trades to the shipping business. With many more ports to visit and often less efficient port itineraries, they generate more business than the container volume suggests. Although most trades are now containerized, a considerable amount of break-bulk cargo still cannot be handled in containers, so the liner services are more varied. These trades are too extensive to review in detail, so we will concentrate on one example, the Europe to West Africa service.

The Europe to West Africa trade operates between north-western Europe and the 18 countries of West Africa, stretching from Senegal down to Angola. Nigeria is comparatively rich, but many of the others are very poor with few ports and limited supporting transport infrastructure. European trade accounts for two-thirds of the seaborne traffic, with the remainder divided between the USA and a rapidly growing trade to Asia.[31] Southbound shipments include machinery, chemicals, transport equipment, iron and steel, machinery and various foodstuffs. The return cargo is principally composed of primary products and semi-manufactures such as cocoa, rubber, oilseeds, vegetable oil, cotton, petroleum products and non-ferrous metals. The volume of cargo southbound is higher than the volume northbound, which creates problems fully utilizing the vessels.[32]

In 2005 the main services were containerized, though ro-ros and MPP vessels continue to operate in the trade. These services tend to be more flexible than the deep-sea container services, varying the ships and services to meet the needs of the trade. For example, a typical service, shown in Figure 13.6, offers weekly container-ship sailings with less frequent break-bulk sailings. The ships load cargo in Europe at Felixstowe, Rotterdam, Antwerp, Hamberg and Le Havre. In West Africa the line offers shipment to virtually all major ports either direct or via a feeder system. The service in Figure 13.6 calls at Felixstowe, Antwerp and Le Havre in north-western Europe, whilst in West Africa the itinerary is Dakar, Abidjan, Lomé and Cotonou on the southbound leg, and Tema, Abidjan and Dakar on the northbound leg. To provide this service a fleet of five 1600 TEU containerships is used. Other services use break-bulk ships. For example, a service using six 660 TEU ro-ros offers sailings every 8 days, calling at 13 ports and carrying rolling stock and project cargo in addition to containers.

The imbalance of containerized cargo leaves the shipping line with empty containers to transport back to Europe, and strenuous efforts have been made to containerize return cargoes in order to utilize the container space on ships. On the West Africa to Europe leg the following commodities were containerized: coffee (bagged in containers), empty gas cylinders (returned for refilling), high-value veneers, ginger, cotton, and mail. Attempts to containerize cocoa were initially unsuccessful because the product sweats, while the large logs shipped from West Africa are not generally suitable for containerization. About two-thirds of the containers shipped out to West Africa thus travel back empty.

This is just one example of the North–South liner services. A sense of the way these services develop is given by the press release shown below:

> Launch of Africa Service
>
> Hapag-Lloyd is starting its new weekly service from Europe to South Africa in October 2006. The relevant organisation is already in place in South Africa.
> [The new service will not use] charter ships as originally planned, but after further studying the market, as a space charterer from Mediterranean Shipping

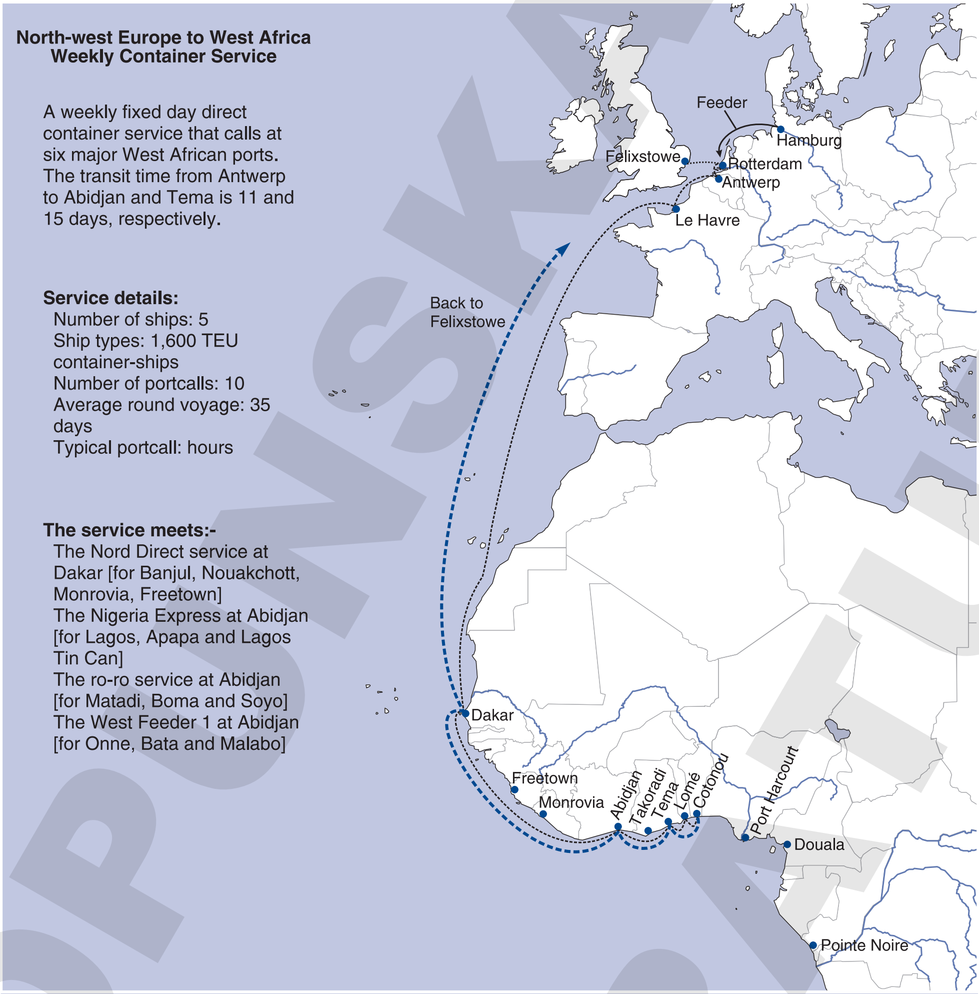


Figure 13.6
Typical North–South Liner service, Europe–West Africa
Source: OTAL container services

Company (MSC), based in Geneva. As a result of the cooperation with MSC, we can offer our customers considerable service improvements with fixed day weekly sailings and refrigerated cargo capacity.

The South Africa Express service (SAX) will link the European ports [of] Felixstowe, Hamburg, Antwerp and Le Havre with Cape Town, Port Elizabeth and Durban. Transit time from Cape Town to Hamburg will be 18 days. The service will start with the first voyage from Felixstowe on Oct. 16th, the first north bound vessel will leave Durban on Oct. 29th.

Hapag-Lloyd has had its own organisation in South Africa with offices in Durban, Cape Town and Johannesburg since the beginning of July 2006.[33]

Intraregional trades and feeder services

In addition to the deep-sea trades, the short-sea services are playing an increasingly important part in the business, especially for the distribution of containers brought into hubs such as Hong Kong, Singapore and Rotterdam. These have grown very rapidly as deep sea operators have moved to bigger ships and reduced their port calls, preferring to distribute cargo from base ports to out ports. Movement of cargoes between local ports is also growing rapidly in response to efforts by regional authorities, especially in Europe, to reduce congestion. Many of the short-sea trades use very small ships and voyages of only 3–4 days, but with the growth of cargo volumes a wide range of vessels of 1,500–2,000 TEU are being used in these trades and even some 3,000–4,000 TEU vessels.

The break-bulk liner services

In discussing the liner trades it is easy to forget that cargo does not fall neatly into general cargo and bulk and there are many borderline trades which do not fit easily into either system. For example, Tasman Orient Line provides transport for New Zealand's forestry exports. It uses thirteen 22,000 dwt MPP liners with a capacity of 350 containers and 10,000 dwt of break-bulk cargo, a speed of 16 knots and 25–35 tonne cranes. The cargoes they carry include containers, reefer containers, car parts, machinery, vehicles, steel products, pulp, paper, lumber, cars, earth-moving equipment and heavy lift cargoes up to 120 tonnes. The vessels operate between New Zealand and South and East Asia. Services like this tend to be very fluid, constantly adjusting to the cargo flow. This is just one of many small and highly specialized liner services which serve the borders of the liner trades.

13.6 THE LINER COMPANIES

The liner companies which operate the services we discussed in the previous section are the third element in the container market model shown in box 3 of Figure 13.1. They have to decide which services to operate, which ships to use and whether to buy their own ships, charter them in, or just buy space on another service. They must also market their services, negotiate service contracts and undertake all the administration involved in the provision of services and the invoicing and accounting. Unlike bulk shipping companies which have a relatively simple management structure in relation to their assets (typically two ships at sea for each person on shore), liner companies are generally more complex and the shore–staff ratio is closer to 40 persons per ship. There are currently about 250 companies offering liner services of one sort or another and they should be distinguished from the independent shipowners in box 4b of Figure 13.1 who invest in container-ships and charter them to liner companies. These companies do not offer liner services themselves, and have more in common with the bulk shipping companies discussed in Chapter 11. A list of the 20 largest liner companies is shown in Table 13.7.

Table 13.7 Twenty largest container fleet operators 1980, 2001, 2005 (year end)

	1980 container fleet				2001 container fleet				2005 container fleet			
	Company	No	'000 TEU	%		No	TEU	%		No	'000 TEU	%
1	Sea-Land	63	70	9.6%	Maersk-SL + Safmarine	297	694	9.4%	Maersk	586	1,665	16.4%
2	Hapag Lloyd	28	41	5.6%	P & O Nedlloyd	138	344	4.6%	MSC	276	784	7.7%
3	OCL	16	31	4.3%	Evergreen Group	129	325	4.4%	CMA-CGM	242	508	5.0%
4	Maersk Line	20	26	3.5%	Hanjin / Senator	82	258	3.5%	Evergreen	155	478	4.7%
5	M Line	17	24	3.3%	Mediterranean Shg Co	138	247	3.3%	Hapag-Lloyd	131	412	4.1%
6	Evergreen Line	22	24	3.2%	APL	81	224	3.0%	China Shipping	123	346	3.4%
7	OOCL	17	23	3.1%	COSCO Container Lines	113	206	2.8%	NOL/APL	104	331	3.3%
8	Zim Container Line		21	2.9%	NYK	86	171	2.3%	Hanjin	84	329	3.2%
9	US Line	20	21	2.9%	CP Ships Group	80	148	2.0%	COSCO	126	322	3.2%
10	American President	15	20	2.8%	CMA-CGM Group	81	142	1.9%	NYK	118	302	3.0%
11	Mitsui OSK	16	20	2.7%	Mitsui-OSK Lines	65	139	1.9%	Mitsui OSK	80	241	2.4%
12	Farrell Lines	13	16	2.3%	K Line	62	136	1.8%	OOCL	65	234	2.3%
13	Neptune Orient Lines	11	15	2.0%	Zim	75	132	1.8%	Sudamericana	86	234	2.3%
14	Trans Freight Line	17	14	1.9%	OOCL	48	129	1.7%	K Line	75	228	2.2%
15	CGM	9	13	1.7%	Hapag-Lloyd Group	32	116	1.6%	Zim	85	201	2.0%
16	Yang Ming	9	13	1.7%	Yang Ming Line	45	113	1.5%	Yangming	69	188	1.9%
17	Nedlloyd	5	12	1.6%	China Shipping	92	110	1.5%	Hamburg-Süd	87	184	1.8%
18	Columbas Line	13	11	1.5%	Hyundai	32	106	1.4%	HMM	39	148	1.5%
19	Safflarine	5	11	1.5%	CSAV Group	54	97	1.3%	PIL	101	134	1.3%
20	Ben Line	5	10	1.4%	Hamburg-Süd Group	45	80	1%	Wan Hai	68	114	1.1%
	Top 20	348	437	60%	Top 20	1,775	3,917	53%	Top 20	2,700	7,387	73%
	All Other Operators	497	290	40%	All Other	1,135	3,475	47%	All Other	938	2,777	27%
	World Fleet	845	726	100%	World Fleet	2,910	7,392	100%	World Fleet	3,638	10,164	100%
	Average market share top 20			3.0%				2.6%				3.6%
	Standard deviation top 20			1.9%				1.9%				3.4%

Source: Pearson and Farsey (1983, Table 9.1, p. 196), CRSL, Martin Stopford

Liner company size

When containerization started, the high capital investment required resulted in consolidation of trades and many hundreds of small liner companies disappeared. However, following this initial period of change, the size profile of the container companies settled down. Table 13.7, which compares the market shares of the 20 largest container companies in 1980, 2001 and 2005, shows that between 1980 and 2001 the size profile hardly changed. In 1980 the biggest operator was Sea-Land with a market share of 9.6% and the other 19 big players had shares ranging from 1.4% to 5.6%, with an average share for the top 20 of 3%. By 2001 Maersk had become the biggest liner company, with a share of 9.4%, having taken over Sea-Land in the late 1990s. P&O Nedlloyd was second with a fleet share of 4.6% and at the bottom of the top 20 was Hamburg-Süd with a fleet share of 1%. In fact during this period the share of the top 20 companies fell from 60% to 53% so the business was not consolidating and the average company had a market share of only 2.6%.

However, over the next five years the shares of the leading three companies increased rapidly. Maersk jumped from 9% in 2001 to 16% in 2005, mainly by acquiring P&O Nedlloyd. In second place in 2005 was MSC with a share of 8%, most of which was built up by acquisition of new and second-hand tonnage (MSC's share was only 3% in 2001). The other company which grew rapidly was CMA-CGM, which again built up capacity to around 5% by acquiring Delmas and buying ships. Despite these changes at the top, the companies in the middle of the table held onto their market share pretty well and many increased their share. It was the companies below the top 20 which lost market share, falling from 47% in 2001 to 26% in 2005. So the general conclusion from Table 13.7 is that the size distribution of liner companies does change, though not always in the same direction. In such a short period, dominated by unusual market circumstances, it is difficult to judge whether this sprint for growth has proved effective or not.

Finally, we can note that there was a trend for the larger liner companies to deal with the capital intensity problem by removing the ships from their balance sheet. This was achieved by leasing the ships or chartering them from independent operators. In the early 1990s few ships were chartered, but by 2005 about 50% of the container-ship capacity operated by the 20 largest container-ship companies was being time-chartered from independent owners, often financed through the German KG system (see Chapter 8).

Strategic and global alliances

Under the commercial pressure to achieve greater economies of scale through bigger ships and at the same time provide more frequent global services, in the mid-1990s the medium-sized container companies started to form alliances. These agreements integrated the operational aspects of each participant's services, whilst leaving the commercial activities in the hands of the individual companies.[34] So the alliances typically cover operating joint services on the major liner routes, chartering in vessels, slot sharing, shared terminals, pooled containers, coordinated feeder and inland services where permitted, and information sharing. However, although there is often complete operational integration, each member retains its corporate identity and executive management, including sales and marketing, pricing, bills of lading and vessel ownership and maintenance.

The first of these, the Global Alliance, was formed by APL, OOCL, MOL, and Nedlloyd in May 1994, followed soon afterwards by the Grand Alliance consisting of Hapag-Lloyd, NOL, NYK, and P&OCL, and in 1995 a third alliance of Maersk and Sea-Land with a total of 206 ships. A decade later in 2006 there were three major alliances in operation, the Grand Alliance, the New World Alliance and CKYH. The Grand Alliance, with 152 ships, offered eight services between Europe and the Far East; 11 transpacific services, and four on the North Atlantic.[35] Its members controlled 17%

of the container tonnage. The New World Alliance had three members, APL, Hyundai Merchant Marine and Mitsui OSK Lines Ltd, and 90 ships, whilst the parent companies together controlled 6% of the container tonnage. The third, CKYH, included COSCO, K-Line, Yang Ming and Hanjin, and had 162 ships.

The liner market model

Liner companies operate in a complex economic environment, and the business model helps to put the issues of company size and competition into perspective. Figure 13.7 sets out the basic elements of the model, with the market place for container transport in the centre of the diagram and the competitive process divided into two parts – part (a) is concerned with the market variables which set the tone of the market in which liner companies operate, whilst part (b) is concerned with the strategic variables over which liner companies have some influence. Part (a) identifies three factors which determine the market environment – (a1) the degree of rivalry between liner companies; (a2) barriers to entry; and (a3) the availability of substitutes such as air freight. Part (b) focuses on the company's bargaining power with suppliers (how powerful are they?) (b1); its bargaining power with customers (how strong is their bargaining position?) (b2); and the extent to which the company can differentiate its service and strengthen its competitive position (b3). Looked at in this way, we have the basic ingredients to explain such factors as market concentration, the company size profile and long-term profitability.

If profitability is any guide, competition in the liner market is severe and despite containerization, liner services are not much more profitable in the twenty-first century than they were in the 1960s before containerization appeared on the scene. In the 1960s British shipping companies earned a return of 6% on assets, about half the industrial average at that time. In the period 2000–5, a generally prosperous time for shipping, the profit earned by one of the largest container companies ranged from 4% to 10% of total assets.[36] Admittedly company rivalry (see (a1)) in Figure 13.7 is moderated by the various conferences

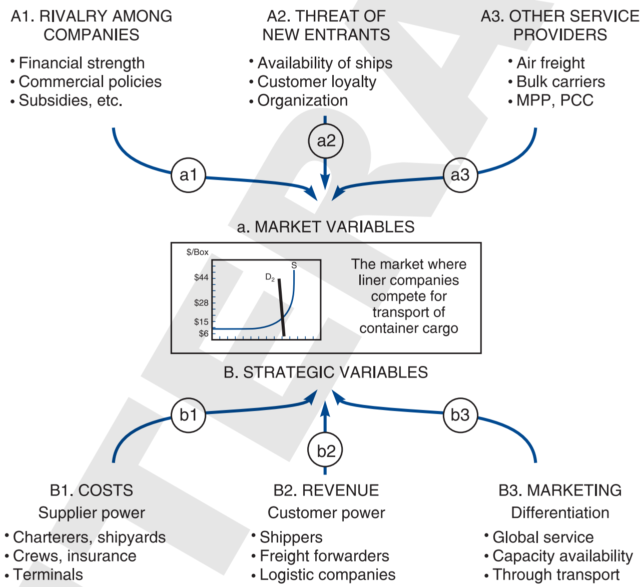


Figure 13.7
Liner industry business model
Source: developed from Porter (1990)

and alliances which were tolerated by regulators because they seemed to offer a degree of stability in a volatile business environment. However, new companies can enter the market with increasing ease (see (a2)). The container-ship charter market and a pool of skilled labour make setting up a new service relatively straightforward and the fragmented geographical route structure provides plenty of opportunities to compete against established companies on relatively equal terms. Finally, other service providers (see (a3)) such as air freight, bulk and multi-purpose operators compete for specialized cargoes. Of course this is a two-way street – their cargo is also a potential target for the container companies.

The strategic variables provide the liner companies with the raw material for competing in this market. As far as costs are concerned (see (b1)), the liner business is dealing with charterer-owners who provide ships; the shipbuilders who build new ones; crews, insurers, chandlers and bunker suppliers; terminals; and the subcontractors such as road haulage. This is a difficult area because regional fragmentation probably dilutes the leverage big companies have over these suppliers. For example large supermarket chains can use their bulk purchasing power to exert pressure on suppliers, and companies with over 25% of the market are in a strong position. There is no parallel for this in the liner business and although size may be helpful, geographical fragmentation dilutes the benefits and consolidation does not necessarily add value in terms of enhancing the company's competitive position on individual routes.

On the revenue side (see (b2)), liner companies face powerful customers, including large cargo shippers, for example multinational corporations producing electronic goods, mechanical equipment, motorcycles and textiles. Customer strength is often a real issue because large cargo shippers run professional transportation operations and squeeze their transport budget very hard. One route to strength is service differentiation (see (b3)), though this is not easy. Ultimately the transport service provided is a commodity, so differentiation is difficult. Where shippers are smaller, freight forwarders and logistics companies provide the interface, and in a geographically fragmented market with many different routes, these intermediaries often have a strong negotiating position in their local area, though many are global in their spread. Company size only really matters when it generates strength in one of these areas.

In summary, there is plenty of flexibility over the way a liner company develops its business. On the cost side, it can use new or old ships, either purchased or on charters; it can select the size of ships it uses and tailor its approach to terminals. On the revenue side, the company can choose whether it specializes as a niche player on a small selection of local routes, or casts its role wider as a global carrier. Again there are many options which can be followed. Finally, there is the question of service differentiation, and the variety of cargoes offers range of potential markets. The way this works out in practice was illustrated in Table 13.7, which shows that the concentration of ownership is relatively low. In the retail business, for example, the top three or four retailers in national markets such as the USA often have a market share over 60%. Even with recent consolidation, the liner business has half that.

13.7 THE LINER FLEET

Types of ship used in the liner trades

Now we turn to the fleet of ships used in these trades. Just as in other sectors of the shipping market, the fleet is not an optimum. It is the result of 20–30 years of investment decisions. Although some of the vessels in the fleet are now technically obsolete in some way or another, the fact that they are still trading is evidence that they retain economic value. Although predominantly container-ships, the fleet used in the liner trades actually includes six different types of ships, shown in Figure 13.8:

- *Container-ships*. Cellular 'lift on, lift off' container-ships are now the biggest and most modern part of the fleet, with 138 m.dwt in September 2007. All the ships in this fleet have open holds with cell guides and are designed exclusively for the carriage of containers.
- *Multi-purpose vessels*. There was a fleet of 2647 vessels of 24.1 m.dwt in September 2006. These are ships designed with a fast speed, good container capacity and the ability to carry break-bulk and other unitized cargo such as forest products. They were mainly built during the early years of containerization when operators were handling a mix of containerized and break-bulk cargo, often with open holds without cell guides and often incorporating a 'tween deck. In the early twenty-first century the fleet found a new niche in the transport of heavy lift and project cargoes. MPPs are also used in services, for example, between Oceania and South East Asia where the ability to carry mixed break-bulk cargoes provides a competitive advantage. After some years of decline the fleet has started to grow again.
- *'Tweendeckers*. These flexible tramp vessels continued to be built until the 1980s, and in 2007 there was still a fleet of about 5.6 m.dwt in operation. Two standard designs, the SD14 and the Freedom, were very popular. 'Tweendeckers have two decks, narrow hatches, economical speed, limited container capacity and cargo gear.

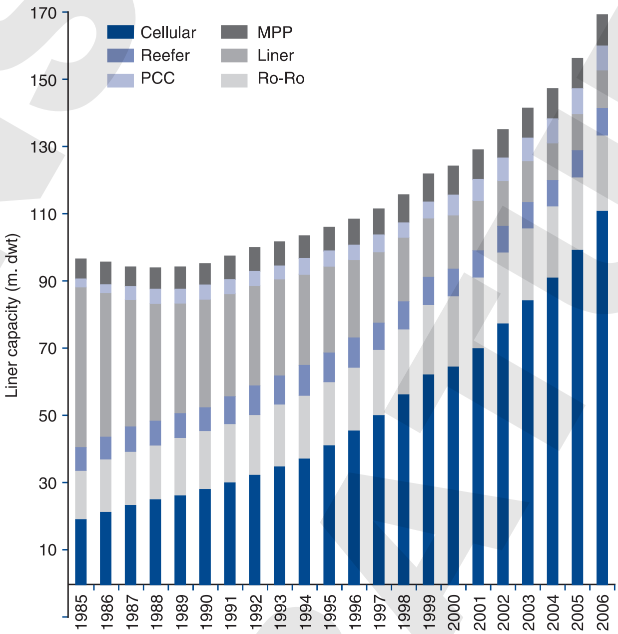


Figure 13.8
Liner fleet by vessel type, 1985–2006
Source: Clarkson Research Services Ltd

- *General cargo liners*. These are purpose-built cargo liners still in service. They are fast with multiple decks, extensive cargo gear but poor container capacity and as the old ships were scrapped and not replaced the fleet shrunk to 5.5 m.dwt in 2007 (the *Pointe Sans Souci*, mentioned earlier in this chapter, was scrapped in 1996).
- *Ro-ros*. Multi-deck vessels in which the holds are accessed by ramps in the bow, stern or side. Although sometimes similar in design to car ferries, they have no accommodation or public areas and are designed primarily to carry cargo on deep-sea routes. The fleet, which includes ferries, edged up to 12.6 m.dwt in 2007.
- *Barge carriers*. A 1970s experiment which did not catch on, these carry 500-ton standard barges which are floated or lifted on and off the ship. There were about 50 of these vessels still operating in 2007 (including some heavy lift).

The number of container-ships increased from 750 in 1980 to 4208 in September 2007, and they now dominate the liner fleet, accounting for 60% of the total deadweight capacity. This compares with a tanker fleet of 4467 vessels and a bulk carrier fleet of 6557 vessels, making container-ships a very significant part of the merchant fleet. The container-ship fleet is usually measured in TEU. The ships have wide hatches designed to standard container dimensions and cell guides in the holds and sometimes on deck. An example of a 1769 TEU container ship is shown in Figure 14.3, along with technical details. The bigger ships tend to be faster. For example, Feeder container-ships of 100–299 TEU have an average speed of 13.8 knots, while many of the ships over 4,000 TEU have an average speed of 24 knots.[37] This reflects the fact that smaller ships generally operate on short routes where high speed brings fewer economic benefits.

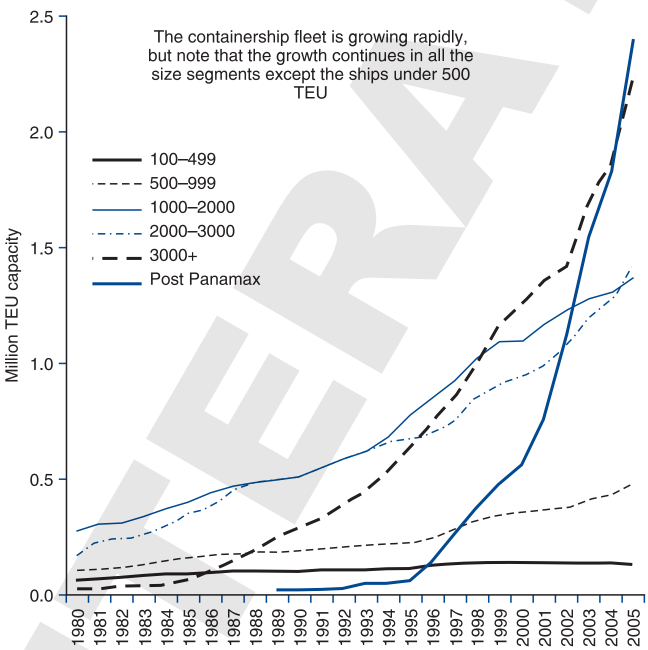


Figure 13.9
Container-ship fleet by ship size, 1980–2005
Source: Clarkson Research Services Ltd

Container-ship size trends

One of the principal benefits of containerization is that it allows bigger ships to be used and the size of container-ships has increased steadily, following much the same process of evolving into size segments we have already seen in the tanker and bulk carrier markets, each serving a different part of the market. Figure 13.9 shows the segments developed between

1980 and 2005. The smaller sizes (Feeder, Feedermax and Handy) are mainly used in the short-sea trades and in draught-restricted ports on the North–South routes. The medium-sized vessels of 1,000–2,000 TEU are flexible enough for short-sea operations, large feeder services and North–South trading. The larger segments (sub-Panamax, Panamax, and post-Panamax) serve the long-haul deep-sea business. At the upper end, the Panamax fleet (over 3,000 TEU and able to transit Panama) has grown most rapidly in recent years, with a new generation of post-Panamax vessels appearing in the 1990s.

13.8 THE PRINCIPLES OF LINER SERVICE ECONOMICS

The building-blocks of liner service economics

Liner service economics lies at the heart of the issues discussed in this chapter and a practical example helps put things into perspective. We will proceed in two stages, starting with the 'building blocks' from which the liner service is constructed and then buildings a service cashflow model similar to the one used to analyse the bulk shipping industry in Chapter 5. As an example we will take a liner service operating on the transpacific trade and compare the cost structure for six sizes of ship – 1200 TEU, 2600 TEU, 4,000 TEU, 6,500 TEU, 8,500 TEU and 11,000 TEU. The eight main categories of building-block are shown in Table 13.8.

This is not a classification which appears in the accounts of any liner company, and in practice liner companies will not necessarily prepare their management accounts in this way. For example, ship capital costs would probably be allocated across a range of services, rather than attributing specific ships a specific service, as is done in Table 13.8. But in terms of understanding the economics of the business, this is a useful way to group the costs. Based on these operational and cost assumptions the voyage cash-flow for each vessel size is shown in Table 13.9 to give an idea of economies of scale. Of course liner companies operate many services and their published accounts are far more complex than this simple example. However, it serves the important function of identifying the economic variables involved in management decision-making and as the starting point for understanding the principles of liner service economics.

SHIP CHARACTERISTICS

The ship size, speed and cargo-handling efficiency set the economic framework for the service. Size ranges from 1,200 TEU to 11,000 TEU and the size, speed and fuel consumption of each size shown in Table 13.8 are based on averages for the fleet of vessels in 2006. The design speed increases by 38% from 18.3 knots for a 1200 TEU vessel to 25.2 knots for a 6,500 TEU vessel, after which it does not increase, whilst the design fuel consumption shown in the next row is 460% higher for the 6500 TEU ship. In the past a few container-ships were built with speeds over 30 knots, but the industry seems to have settled down at a 25 knot peak. The operating speed shown in the next row can be varied by service planners to leave a margin for weather and delays and also to fine-tune the voyage time to fit with the weekly sailing schedule adopted

Table 13.8 The eight building-blocks of liner costs

Vessel size (TEU)		**1,200**	**2,600**	**4,300**	**6,500**	**8,500**	**11,000**
1. Ship characteristics							
Container-ship size	container-ship characteristics	1,200	2,600	4,300	6,500	8,500	11,000
Design speed (knots)		18.3	20.9	23.8	25.2	25.5	25.5
Design fuel consumption (tons/day)		42	79	147	214	230	240
Operating speed terminal to terminal		17.4	19.9	22.6	23.9	24.2	24.2
Fuel Consumption (tons/day)		36.3	67.7	126.2	183.2	197.2	205.8
Time per port call (days)		0.7	1.0	1.2	1.6	2.0	2.4
2. Service schedule							
Distance of round trip	schedule	14,000	14,000	14,000	14,000	14,000	14,000
Service frequency		weekly	weekly	weekly	weekly	weekly	weekly
Portcalls on round voyage		7	7	7	7	7	7
Days at sea	performance variable	33.6	29.4	25.8	24.4	24.1	24.1
Days in port		5.0	6.7	8.7	11.4	13.8	16.9
Total voyage time (days)		38.5	36.0	34.5	35.8	37.9	40.9
Voyages per annum		9.5	10.1	10.6	10.2	9.6	8.9
Required number of ships in weekly string		**5.5**	**5.1**	**4.9**	**5.1**	**5.4**	**5.8**
3. Capacity utilization (to calculate the number of loaded containers carried)							
Eastbound Capacity Utilization (%)	how full ships are	90%	90%	90%	90%	90%	90%
Westbound Capacity Utilization (%)		40%	40%	40%	40%	40%	40%
Containers shipped outward (TEU)		1,080	2,340	3,870	5,850	7,650	9,900
Containers shipped back (TEU)		480	1,040	1,720	2,600	3,400	4,400
Cargo transported per voyage (TEU)		1,560	3,380	5,590	8,450	11,050	14,300
Annual transport capacity per ship (TEU)		**14,785**	**34,232**	**59,097**	**86,235**	**106,391**	**127,467**
4. Ship costs $ per day							
4.1 Operating costs (OPEX) $/day	capital cost	4,643	5,707	6,000	6,500	7,000	7,500
4.2 Capital cost/$ day		8,904	17,096	23,863	31,699	39,178	46,301
-Capital value $mill		25	48	67	89	110	130
-Depreciation period (years)		20	20	20	20	20	20
-Interest rate (% pa)		8%	8%	8%	8%	8%	8%
4.3 Bunker cost ($/day)	bunker cost	12,690	23,700	44,160	64,110	69,000	72,000
-Bunker price $/ton (average)		300	300	300	300	300	300
4.4 Total cost per vessel TEU capacity per day($/day)		648	496	457	433	395	360
4.5 Cost per container transported per annum ($)		**648**	**496**	**457**	**433**	**395**	**360**

Table 13.8 The eight building-blocks of liner costs—cont'd

Vessel size (TEU)		1,200	2,600	4,300	6,500	8,500	11,000
5. Port & charges (excluding cargo handling)							
Port cost $/TEU		22	15	12	11	11	10
Port cost $/call		22,000	29,000	35,000	43,000	60,000	65,000
6. The deployment of containers							
20' containers (% ship capacity)	mix of boxes needed to operate service	14%	14%	14%	14%	14%	14%
'-Number of units loaded		168	364	602	910	1,190	1,540
40' containers (% ship capacity)		80%	80%	80%	80%	80%	80%
-Number of units loaded		480	1,040	1,720	2,600	3,400	4,400
Reefer containers (% total)		6%	6%	6%	6%	6%	6%
-Number of 40' units loaded		36	78	129	195	255	330
Total units on full vessel (all sizes)		684	1,482	2,451	3,705	4,845	6,270
Container turnaround time (days/voyage)	efficiency variables	75	75	75	75	75	75
Inter-zonal repositioning (%)		10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
7. The cost of containers and container handling							
Container costs ($/TEU/day)	20 foot	0.7	0.7	0.7	0.7	0.7	0.7
	40 foot	1.1	1.1	1.1	1.1	1.1	1.1
	40 foot reefer	6.0	6.0	6.0	6.0	6.0	6.0
Maintenance & repair ($/box/voyage)		50.0	50.0	50.0	50.0	50.0	50.0
Terminal costs for container handling ($/lift)		220	220	220	220	220	220
Refrigeration cost for reefer containers ($/TEU)		150.0	150.0	150.0	150.0	150.0	150.0
Trans-shipment by sea ($/TEU)		225.0	225.0	225.0	225.0	225.0	225.0
Inland intermodal transport cost ($/TEU)		220.0	220.0	220.0	220.0	220.0	220.0
Interzone re-positioning ($/TEU)		240.0	240.0	240.0	240.0	240.0	240.0
Cargo claims ($/box/voyage)		30	30	30	30	30	30
8. Administration costs							
Administrative productivity (TEU/employee)		640	640	640	640	640	640
Number of employees required		23	53	92	135	166	199
Cost/employee $ per annum		60,000	60,000	60,000	60,000	60,000	60,000
Administration cost ($000/voyage)		146	317	524	792	1,036	1,341

Source: CRSL, HSH Nordbanlk, Drewry Shipping Consultants

Table 13.9 Liner voyage cashflow model ($000 per voyage)

Vessel size (TEU)	1,200	2,600	4,300	6,500	8,500	11,000
	$000s					
1. Cost of the ship on the voyage						
1.1 Operating costs	179	206	207	232	265	307
1.2 Capital costs	343	616	824	1,134	1,485	1,896
1.3 Bunker costs	426	696	1,139	1,562	1,662	1,734
1.4 Port costs	154	203	245	301	420	455
1.5 Total ship costs	1,102	1,721	2,415	3,229	3,832	4,392
1.6 Ship costs, % of total costs	54%	46%	42%	39%	37%	34%
2. Costs of the containers on voyage						
2.1 Cost of supplying containers	32	65	104	162	225	314
2.2 Cost of container maintenance	34	74	123	185	242	314
2.3 Total container cost	66	139	226	347	467	628
2.4 Container cost, % of total cost	3%	4%	4%	4%	4%	5%
3. Administration cost						
3.1 Administrative cost per voyage	146	317	524	792	1,036	1,341
	7%	9%	9%	10%	10%	10%
4. Cargo handling and onward transport						
4.1 Terminal costs for container handling	301	652	1,078	1,630	2,132	2,759
4.2 Refrigeration cost for reefer containers	11	23	39	59	77	99
4.3 Inland intermodal transport cost	343	744	1,230	1,859	2,431	3,146
4.4 Interzone repositioning	58	125	206	312	408	528
4.5 Cargo claims	47	101	168	254	332	429
4.6 Total handling & onward transport	713	1,544	2,553	3,860	5,047	6,532
4.7 Handling and onward transport, % of total cost	35%	41%	45%	47%	49%	51%
5. Voyage cost						
5.1 Total voyage cost	2,027	3,721	5,719	8,229	10,382	12,892
5.2 Cost Per TEU eastbound leg	938	795	739	703	679	651
5.3 Cost Per TEU westbound leg	2,111	1,789	1,662	1,582	1,527	1,465
5.4 Average cost/TEU	1,299	1,101	1,023	974	940	902
5.5 % change in average cost/TEU		–15.3%	–7.1%	–4.8%	–3.5%	–4.0%
6. Voyage revenue ($000s)						
6.1 Freight rate per TEU eastbound leg	1,750	1,750	1,750	1,750	1,750	1,750
6.2 Freight rate per TEU westbound leg	750	750	750	750	750	750
6.3 Total revenue eastbound leg	1,890	4,095	6,773	10,238	13,388	17,325
6.4 Revenue westbound leg	360	780	1,290	1,950	2,550	3,300
6.5 Total voyage revenue	2,250	4,875	8,063	12,188	15,938	20,625
7. Voyage profit (loss) ($000s)						
Voyage profit (loss)	223	1,154	2,344	3,959	5,555	7,733
% total revenue	10%	24%	29%	32%	35%	37%

in section 2 of the table. In this case as a neutral assumption the operating speed is set 5% below the design speed. Finally, the time per call shown in the last row of section 1 assumes half a day for entering and leaving port, plus one minute per lift, with 25% of the cargo being handled on each call. These assumptions will differ widely in practice.

THE SERVICE SCHEDULE

The service schedule described in Table 13.8 is based on the 14,000-miles transpacific round voyage we reviewed in Figure 13.3. Service planners have to decide the frequency of sailings and the number of port calls, and this example is based on a weekly service with seven port calls on the round voyage (e.g. Shanghai, Kobe, Nagoya, Tokyo, Sendai, Oakland and Los Angeles), giving a round voyage time of 41.9 days for the slow 1,200 TEU ship and 42.3 days for the faster but much bigger 11,000 TEU ship. This raises the interesting point that the faster 11,000 TEU ship's shorter sea passage is offset by the longer port time needed to handle its cargo. From a practical viewpoint the 35.8 days for the 6,500 TEU ship fits pretty well with the actual schedule in Figure 13.3. The bottom line of section 2 in Table 13.8 shows that the number of ships required to run the service varies from 4.9 for the 4,300 TEU ship to 5.8 for the 11,000 TEU ship, reflecting the interplay between the speed and port time of the different ship sizes. In practice, the service planners would have to adjust the operating speed of the ships and the number of port calls to get the best balance. Or they could add a sixth ship to the string and operate at a lower speed, which would incur more capital costs, but save bunker costs. The possibilities are endless, but in this example for simplicity we will not do this.

CAPACITY UTILIZATION

Getting the capacity right is crucial for service planners. There is no point in using big ships if you cannot fill them, but running out of space can be just as bad. For example, to fill the biggest ships, ten port calls might be needed rather than seven and since each port call takes an average of 1.25 days, this would extend the round voyage time to 40 days, requiring a six-ship string. One way round this is to set up regional hubs where cargo is collected for despatch on the deep-sea service, but that involves multiple handling and shippers often prefer direct services. Or a niche operator might decide to use a smaller ship and make only one port call at each end (a 'direct service'), cutting the round voyage time to around 25 days for the medium-size ships, allowing a string of four vessels to be used. There is also the issue of trade imbalances. For example in the transpacific trade there is always much more cargo moving east, and in Table 13.8 we assume 90% capacity utilization on the eastbound voyage and 40% on the west-bound voyage. With these figures we can calculate the cargo transported on each voyage, and the annual transport capacity is shown in the final two rows of section 3. Each 1,200 TEU vessel transports 14,785 TEU in a year, whilst the 11,000 TEU vessel transports 127,467 TEU.

SHIP COSTS AND ECONOMIES OF SCALE

So far we have concentrated on the physical aspects of liner service, but the size of ship also has an economic dimension because some costs do not increase proportionally with the transport capacity of the ship. The economies of scale generated by the three main elements in the ship cost calculation – capital costs, operating expenses, and bunker costs – are examined in section 4 of Table 13.8:

- *Operating costs (OPEX)*. The operating expenses of the ship are crew, insurance, stores, maintenance and administration. Some of these items offer more scale economies than others. Administration, stores and crew generally do not increase very much as the ship gets bigger. For example the *Emma Maersk*, the industry's first 11,000 TEU container-ship, was designed for a crew of 13, significantly fewer than many 3,000 TEU ships. However, insurance and maintenance costs are likely to increase in line with the capital cost of the ship, though by less than the transport capacity of the ship. The OPEX numbers in Table 13.8, which are based on a survey of German containerships,[38] show that the daily cost increases from $4600 per day for a 1,200 TEU ship to around $7,000 per day for an 8,500 TEU ship, so there are significant scale economies here.
- *Capital costs*. Capital costs are subject to economies of scale because big ships cost less per container slot than small ones. For example, in 2006 a 1,200 TEU containership cost $25 million ($20,000 per slot) whilst a 6,500 TEU ship with five times the capacity cost about $89 million ($13,700 per slot). However, the saving diminishes as the ship gets bigger and beyond 5,000 TEU is not very great because the major fixed cost is the engine room and bigger ships are mainly adding more steel, which is not subject to the same degree of economies of scale.
- *Bunker costs*. Finally, there is fuel consumption and again we see the now familiar pattern of diminishing economies as the ship gets bigger. Figure 13.10 plots the average bunker consumption of ships in the container-ship fleet in 2006, adjusted to a standard 15 knot speed, against TEU

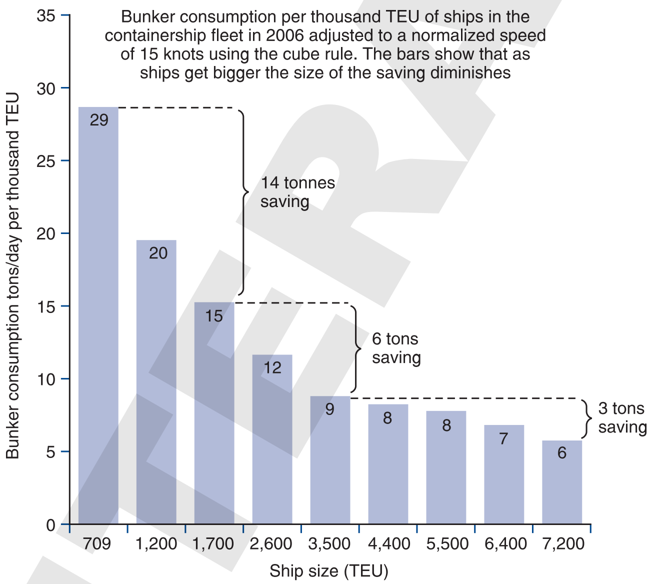


Figure 13.10
Bunker consumption of container-ships, 2006
Source: Clarkson Reseach Services Ltd

capacity for a sample of 2,500 container-ships.[39] Increasing the ship's capacity from 700 to 1700 TEU cuts bunker consumption by 11 tons per thousand TEU; from 1700 TEU to 3500 TEU by another 6 tonnes per thousand TEU; and from 3500 TEU to 7200 TEU by only 3 tons per thousand TEU. It follows that the biggest benefits come from upsizing the smaller segments of the container business.

The economies of scale for each size of ship are summarized in Figure 13.11 in terms of the cost per TEU transported in a year for each ship size (the numbers are in Table 13.8, row 4.5). The cost of $648 per TEU for a 1200 TEU vessel falls sharply to $498 TEU for a 2600 TEU vessel; $457 TEU for a 4,300 TEU vessel; and $360 TEU for an 11,000 TEU vessel. So the 11,000 TEU ship halves the cost of container transport. Beyond 2600 TEU economies of savings are roughly 5% for each additional 1,000 TEU capacity (but remember this is just an illustration and the savings depend on the assumptions). Finally, there may be diseconomies of scale. Using very big ships means deep dredging of hub ports and necessitates feeder services to ports which cannot accommodate them. These feeder costs detract from the savings on using bigger ships on the deep-sea leg.

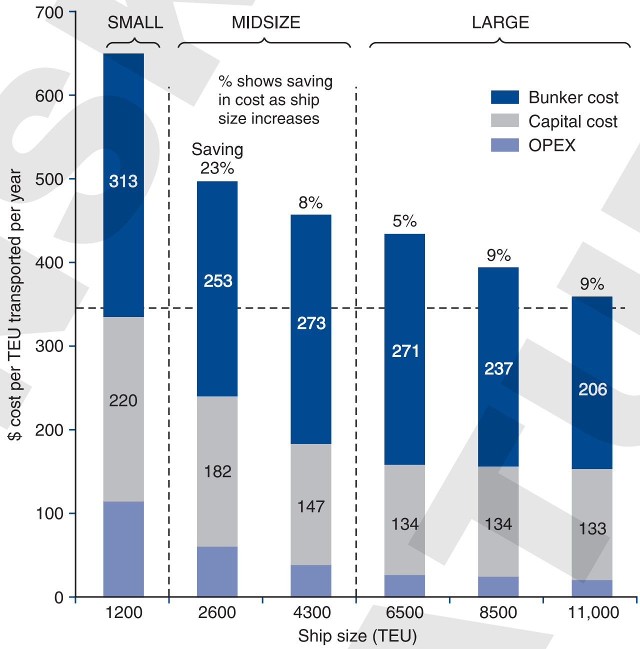


Figure 13.11
Container-ship cost per TEU transported
Source: Table 13.8

PORT CHARGES

These are an item over which the shipowner has less control, since they vary from port to port, though big groups have a stronger negotiating position. Since port charges are generally levied on the basis of the ship's tonnage, this introduces an additional element of economies of scale, since the port costs per TEU reduce as the ship gets bigger. In Table 13.8, Section 5, we assume a reduction in the port costs per TEU from $22 for the 1,200 TEU ship to $10 for the 11,000 TEU ship. This creates an incentive to develop ship designs with a low tonnage relative to capacity, especially for distribution trades where the vessels make many port calls, encouraging designs with a low deadweight and gross tonnage per TEU.

DEPLOYMENT OF CONTAINERS

This involves two main issues. First, there is the mix of container types for the trade. There are many different sizes of containers (see Table 13.1), including general purpose and specialized designs. In the transpacific trade the split is about 15% 20 ft containers, 80% 40 ft containers, and 6% refrigerated units, though the balance differs in other trades. For example, on the shorter transatlantic journey the proportion of 40 ft containers reduces to about 60%. There may also be a requirement for specialized containers, for example open-top containers or tanks. Most liner companies own a substantial proportion of their containers, since this is generally the cheapest option, and lease a proportion, say 20–30%.

Then there is the efficiency of container turn-around. Between voyages the containers must be delivered to the customer, collected and repositioned for the next cargo. This calls for a substantially greater container stock than the container capacity of the vessels employed in the trade. In this example, we assume a 75-day turn-around time for the cycle, of which 28 days are spent at sea and 47 days in transit to and from the customer. Naturally this will vary a great deal with the trade. Finally, trade imbalances on particular routes mean that some containers must be repositioned empty, which includes the significant cost of loading and unloading the empty container. In section 2 of Table 13.8 we assumed only 40% of the containers are filled on the westbound leg compared with 90% on the eastbound leg, so 50% of the westbound containers are empty. This is a classic opportunity for marginal cost pricing. If the container is travelling empty, any cargo which pays more than the handling charges is worth carrying. Hay, waste paper, building blocks, animal feeds and a host of other cargoes fall into this category. The danger arises when these marginal cargoes create hidden costs which are unseen by the salesman and end up being shipped at a loss.

CONTAINER COSTS

These cover the capital cost of the containers; maintenance and repair; terminal costs for container handling (i.e. the cost of lifting it on and off the vessel); storage for reefer units; on-shipment costs by sea or inland; repositioning empty containers between zones; and cargo claims. The cost of the container itself depends on the purchase price, its economic life and the method of finance. In 2006 a 20 ft container cost about $2,000 and a 40 ft container about $3,200. Refrigerated containers are much more expensive, costing over $20,000 for a 40 ft unit. In practice containers have an average life of 12–16 years, at the end of which they have a scrap value of several hundred dollars. On these parameters the daily cost of a container can be calculated, working out at about 60 cents per day for a 20 ft unit and $1 per day for a 40 ft unit, whilst reefers are about $5.60. Like ships, containers and other equipment require continuous maintenance, for which an annual budget must be allowed.

Terminal and through transport costs vary enormously from port to port. Handling the container in the terminal includes the lift on or off the ship and the associated costs of moving, stacking and storing the container within the terminal. These costs depend on the facilities available and local stevedoring conditions. For simplicity the handling charges in Table 13.8 are limited to a single rate of $200 per lift. Refrigerated containers also require special terminal services which are costed here at $150 per unit. The on-shipment of the container is dealt with under three headings: trans-shipment by sea, inland inter-modal transport and inter-zone repositioning. These costs depend specifically on the trade and the method of pricing adopted by the company. Some operators charge separately for delivery, in which case the freight rate does not include the cost of on-transport. Other carriers offer 'door-to-door' rates. Since some cost will certainly be incurred, Table 13.8 assumes values of $225 per TEU for transhipment, $200 for inland transport, and $240 for inter-zone repositioning when regional imbalances appear and the containers have to be shipped to a different part of the world. Finally, there is an item for cargo claims. Concluding the discussion on container costs, perhaps the most significant feature is that because these costs are based on the standard container, they are not subject to economies of scale. The 11,000 TEU ship faces the same unit costs as the 1,200 TEU ship.

ADMINISTRATION COSTS

Somehow the shipping company must recover the cost of running a global container service. If the profitability of each part of the business is to be calculated accurately, it is important to allocate costs fairly to those parts of the business which incur them so that the profitability of different parts of the business can be measured. One common way to do this is to charge an administration cost to each vessel on a proportional basis which recovers the full overheads of the company. This is the approach we use in Table 13.8, though the charging could also be done on a service basis.

A rough idea of the nature of these costs and the way they might be organized is given by the organization chart in Figure 13.12. The chart divides management responsibility between profit centres responsible for the trade routes on which the company is active and functional departments responsible for providing efficient and cost-effective services. Managers of the trade routes, shown in the first row of the organization chart, are responsible for running profitable services. They interface with the customers and carry out many functions locally. However, in the drive for efficiency, functional activities are managed and coordinated centrally on a matrix basis and their costs charged out to the profit centres. The example in the chart shows four functional departments, each responsible for a specific activity as follows:

- *Operations and logistics*. This covers the management of the ships, scheduling, cargo stowage and terminals. If the company has many terminals this could be a separate department. It is also responsible for the overall maintenance and control of the company's fleet of owned and leased containers, including maintenance, repair and scheduling.
- *Finance and admin*. A major activity including management accounts and budgeting; voyage accounts (e.g. booking, rating, tracking, billing.), compliance, human resources and general administration.
- *Global sales*. This covers the booking and documentation of cargo, plus dealing with insurance and conferences where appropriate, plus pricing, service agreements, public relations, and advertising and agents.

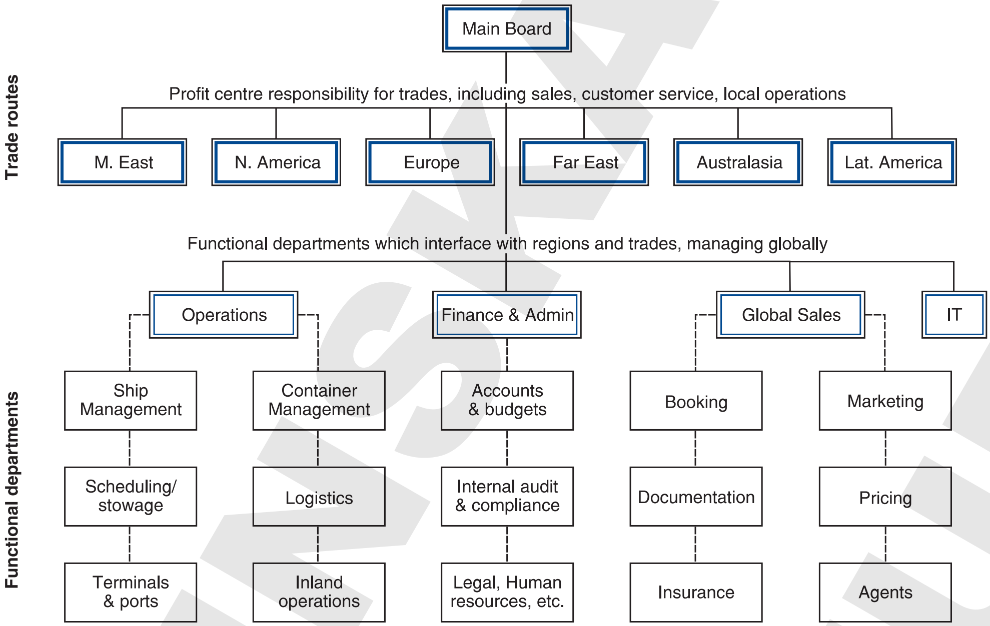


Figure 13.12
Liner company organization chart showing main regional and functional activities
Source: complied from various sources

- *IT*. This is a vital part of the modern global business, managing and developing the communications and computer systems used in the various offices.

The cost of these departments could be charged back to the trade route profit centres as a direct charge, or charged to the ships they use, as in Table 13.9.

Some companies carry out all of these activities themselves, while smaller companies may subcontract. As a result the numbers on the payroll vary a great deal. For example, in 1995 Atlantic Container Line shipped 224,000 containers on the North Atlantic and had a staff of about 380, a throughput of 588 TEU per employee. The salary cost was $91 per TEU. A decade later in 2005, Hapag-Lloyd shipped 2.67 million TEU with a workforce of 4,161, an average of 640 TEU per employee and we assume in Table 13.8, Section 8 that this applies to all ship sizes, requiring 23 employees for the 1,200 TEU ship and 199 for the 11,000 TEU ship.[40] With a cost per employee of $60,000 per annum the 1,200 TEU ship, which carries 1,560 TEU per voyage, will incur an administrative cost on the voyage of $146,000 (i.e. 38.5 days on the voyage at a daily cost of $3,797 per day).

The liner voyage cash flow model

Now we can combine the costs with revenue to calculate the financial performance of the liner service just as we did for bulk shipping in Chapter 7 (see Table 7.11). The *voyage cashflow model* shown in Table 13.9 uses the cost information from Table 13.8

to calculate the cost of the ships (section 1), the cost of the containers (section 2), the administration cost (section 3) and the cargo-handling and onward transport cost (section 4). From these items we calculate the voyage cost per TEU in section 5 and add the voyage revenue based on the freight rate on each leg (section 6) to obtain the voyage profit or loss in section 7. Finally, to give a sense of how costs and profits can vary with ship size, Table 13.9 compares the results for the six vessel sizes. We will now discuss each of these items in more detail.

The ship costs shown in section 1 of Table 13.9 demonstrate why economies of scale are so important to liner operators. The 11,000 TEU ship costs four times as much as the 1,200 ship but carries nine times as much cargo. As a result the ship costs fall from 54% to 34% of the total. In contrast, the cost of containers shown in section 2 does not benefit from economies of scale and increases from 3% of total cost for the 1,200 TEU ship to 5% for the 11,000 TEU ship (Table 13.8, row 2.4). Administration costs, shown in section 3 of Table 13.9, charged on each TEU shipped, range between 7% and 10%. Finally, the various cargo-handling and distribution costs do not benefit from economies of scale and their share of costs increases from 35% for the 1,200 TEU ship to 51% for the 11,000 TEU ship. Drawing these costs together, the average cost per TEU shown in row 5.4 falls from $1,299 for the 1,200 TEU vessel to $902 for the 11,000 TEU vessel.

The freight rate shown in section 6 of Table 13.9, which is based on actual rates in the transpacific trade in late 2006, is $1,750 per TEU on the outward leg and $750 per TEU on the return leg. These are published averages and for many lines the rates would be fixed at different levels under service agreements with bigger shippers. To put these rates into context, about 4,400 DVD recorders can be packed into a 20ft container, so the sea freight would be around 40 cents per unit. On the return voyage around 15,000 bottles of wine can be packed into a container, so the freight per bottle would be 5 cents.[41] Such low levels of transport costs have certainly contributed to the growth of global trade.

At these cargo levels the 1,200 TEU vessel makes a profit of $223,000, a 10% return, while the 11,000 TEU vessel makes a profit of $7.7 million and a return of 37%, so the big ships pay off handsomely – that is, provided the company can fill the ship. In reality, what generally happens is that liner companies order bigger ships, bid competitively for cargo to fill them and slowly the price per TEU falls towards average cost. Once the 11,000 TEU vessels are in service the freight rates fall progressively more slowly towards $810 per TEU, the average cost. This is bad news for any owners who try to hang on with their 1,200 TEU ships. At that freight rate they would lose heavily on the voyage. But for the companies with ships over 4,000 TEU the economies of scale are more marginal. For example, the 6,500 TEU ship makes 32% profit compared with 37% for the much bigger 11,000 TEU ship and in a business of this complexity it is hard to be sure whether this relatively small increase in margin is worth the various limitations imposed by using the bigger ship.

Conclusion

In this section we have focused on costs and revenues for a range of different ship sizes and in Tables 13.8 and 13.9 looked at a simplified example of the economics of running a liner service. We found that although there are strong economies of scale in some aspects of the liner shipping business, especially in the ships and their operating costs, economies of scale are not so strong in other areas, especially the deployment of containers and the costs of container handling and through transport. Since these account for up to two-thirds of the total cost budget, the benefit of using bigger ships is heavily diluted and the analysis demonstrates that economies of scale diminish with size and are more evident below 4,000 TEU than above. This suggests that for larger vessels, considerations such as the volume of cargo expected to be transported now and in future; the shipowner's assessment of the operational merits of running a single string of, say, 12,000 TEU ships compared with two strings of 6,000 TEU ships; and the extent with which diseconomies of scale such as feedering can be overcome are likely to be more decisive than the bottom-line 'theoretical' profitability of the different sizes. Liner investment decisions are a tough call and making these judgements is precisely what shipping companies get paid for.

13.9 PRICING LINER SERVICES

Practical aspects of liner pricing

Now we come to the question of pricing for liner services. Ultimately liner prices, like bulk freight rates, are determined by competition in the market place. Shipping is a business which companies may enter or leave as they wish. However, because of the large fixed overhead and the need to operate regular services, the price-making process is more complex than for the bulk industry and the procedures are constantly changing in response to competitive and regulatory pressures.

During the cargo liner era a centralized system was developed for handling pricing. Liner conferences conducted the price negotiations, usually with a central body representing the shippers, for example a shippers' council. They would meet regularly to negotiate rates and agree 'general rate increases'. Outsiders, whether a small or a large part of the trade, followed an independent pricing policy. The introduction of containerization has diluted this process. Conferences still exist, but the price-making has become less structured, passing to a variety of discussion agreements, alliances and negotiated service agreements.

Liner companies generally try to base their pricing policy on the dual principles of *price stability* and *price discrimination*. The desire for price stability is obvious. Liner companies have fixed overheads, so why not fix prices? Anyway, with so many customers, negotiating every price is not practical. Ideally, once prices are set, they should change only when there is some valid reason, such as a change in the cost of providing the service or a major change in the underlying unit costs. The case for commodity price discrimination is equally obvious. Charge higher rates for commodities which can bear the cost, and discount low value commodities to attract a wider range of cargoes than would be economic if there was a single standard freight charge. By increasing the volume, this permits larger ships and more regular sailings. In this way the pricing policy supports the provision of a better service package for all customers, though the role of cross-subsidization remains one of active debate. The second type of price discrimination is between customers. Large customers, with whom it is worth negotiating, can be offered special discounts through service agreements.

For many years liner companies would set tariff classes and produce a rate book listing the tariff class to which each commodity belonged. The freight rate for a cargo was worked out by looking up the tariff for the commodity in the rate book, multiplying by the amount to be shipped, say 209.5 cubic metres, calculating the total freight and adding any additionals. However, containerization undermined this system by commoditizing the trade. If the tariff worked out at $10,000 to ship a 20 ft container when the shipper knows that boxes are being shipped on the same service for $1,500, it is bound to cause price resistance[42] and many liner companies now charge a standard box rate or apply a 'freight all kinds' tariff. But the fact remains that some shippers are more price sensitive than others (see Chapter 2, Section 2.4). An auto parts distributor might value reliability and service more than the shipper of a price-sensitive product such as cellophane rolls who just wants the cheapest freight. In a business offering a differentiated transport product there is certainly a case for a degree of price discrimination, but this can only work if the product and the pricing system can be adapted to the client's needs. One response has been to transact far more business through service agreements negotiated with each the customer and to offer a range of value added services. Ultimately it is a matter of what the market will bear, and whether the companies can find a form of service differentiation that shippers will pay for.

Even with a 'freight all kinds' rate, the freight invoice often includes charges for services and costs regarded as 'additional' to the basic transport service. Typically the invoice is either sent to the customer after delivery, or settled in advance with additionals invoiced afterwards, and will include some or all of the following items:

- *Freight charges*. The charge for transporting the box or cargo. Sometimes the customer is quoted a 'door-to-door' rate, but often there are separate charges for port-to-port transport, and collection or delivery.
- *Sea freight additionals*. Surcharges to cover unbudgeted costs incurred by the liner company. The *bunker adjustment factor* covers unexpected increases in the cost of bunker fuel, which accounts for a major proportion of operating costs on long routes. The *currency adjustment factor* covers currency fluctuations. The currency adjustment factor is based on an agreed basket of costs and is designed to keep tariff revenue the same, regardless of changes between the tariff currency rates of exchange. *Port congestion surcharges* may be charged if a particular port becomes difficult to access due to congestion.
- *Terminal handling charges*. These are charged per container in local currency to cover the cost of handling the container in the port. Within a region, ports may have different charges. Some operators absorb such changes into the through freight rate.
- *Service additionals*. If the shipper undertakes additional services for the customer – for example, storage of goods, customs clearance or trans-shipment – there would be an additional charge for this.

- *Cargo additionals*. Some cargoes such as open-top containers or heavy lift, attract additional charges because they are difficult or expensive to transport.

As mentioned above, to simplify the charging process companies frequently negotiate service contracts with major customers, offering discounts on volume or other concessions (see Case 4 below).

The principles of liner pricing

The principles of liner pricing can be illustrated with the supply–demand charts shown in Figures 13.13 and 13.14. Consider the case of competing liner companies, each operating a single ship, say a 4000 TEU container-ship which makes five trips a year. Each ship costs $40,000 per day to run, including capital, operating costs and bunkers, and it costs $400 to handle each container. When the ship is full, no additional cargo can be shipped. The vertical axis of each graph shows the price (freight rate) or cost in dollars per TEU, while the horizontal axis shows the number of boxes shipped per trip.

The liner company must charge a price that covers its costs. If this objective is not achieved, in due course it will go out of business. Costs may be fixed or variable. In this simplified case the $40,000 per day cost of the ship is a *fixed cost*[43] because the company is committed to running the

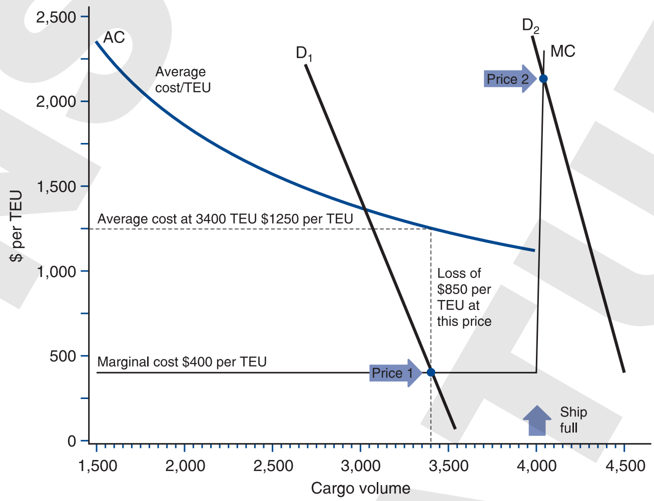


Figure 13.13
Liner pricing, Case 1: Marginal cost pricing
Source: Martin Stopford, 2006

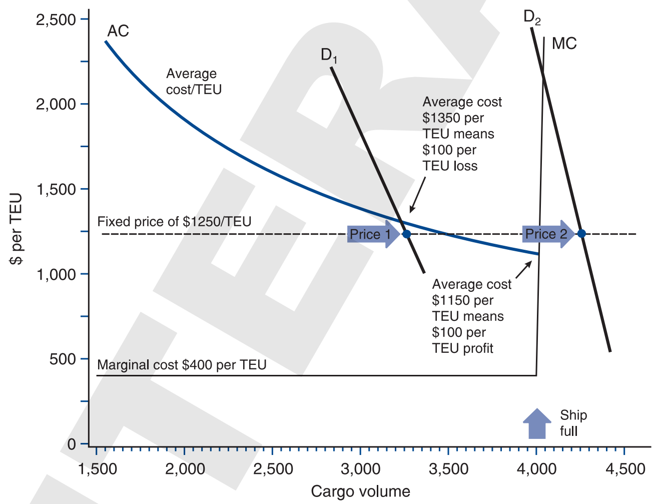


Figure 13.14
Liner pricing, Case 2: Fixed pricing
Source: Martin Stopford, 2006

service regardless of cargo volume, while the cargo-handling costs can be termed *variable costs* because these are not incurred if there is no cargo. This is a great simplification, but serves to illustrate the principle.

Because the company is already committed to the costs of the voyage, when the ship is part empty the only additional cost of accepting another container is the $400 per container cost of cargo handling. This is known as the *marginal cost* (MC). Once the ship is full the marginal cost rises sharply to, say, $2,500 per container, the cost of chartering another ship or hiring slots on another vessel. This is shown by the marginal cost curve (MC) in Figure 13.13. Note that the MC curve is horizontal at $400 from 1,500 TEU to 4,000 TEU when the ship is fully loaded; it then moves up vertically from $400 per TEU to $2,500 per TEU when the cargo load reaches 4,000 TEU. Also shown in Figure 13.13 is the average cost curve (AC), which shows, at each output level, the fixed and variable costs divided by the cargo volume. At low throughput levels the average cost is very high because a small number of containers must absorb the total cost of the ship. For example when the ship is only carrying 1,500 containers the average cost is $2,400 per TEU, but as the load factor increases the average cost falls steadily to $1,150 per TEU when the ship is full.

CASE 1: MARGINAL COST PRICES

To make a profit, the liner company must generate enough revenue to cover the average cost. Figure 13.13 shows what happens in a free market (i.e. without conferences). When there is more shipping space than cargo, which is represented by the demand curve D1, the liner companies bid against each other for the available cargo. As they undercut each other the price falls to the marginal cost which in this example is $400 per TEU (i.e. the handling cost). At this price the cargo volume is 3,400 TEU, the point where the demand curve (D1) intersects the marginal cost curve. This is well below the average cost (AC) which at this throughput level is $1,250 per TEU, so the company makes a loss of $850 per container. With 3,400 containers to transport, that works out at a loss for the voyage of $2.9 million. When demand is high (D2) the price rises sharply to $2,250 per TEU as shippers bid for the limited 4,000 TEU capacity. At this volume the average cost is $1,150 per TEU, so the company makes a profit of $1,100 per container, which works out at $4.4 million on the voyage. To survive in a volatile market with prices determined by competition, the liner company must make enough profit during the good years to subsidize its operations during the bad years. In this case the profit of $4.4 million in the boom more than compensates for the $2.9 million loss in the recession, leaving a surplus of $1.5 million. Although cashflow will be very volatile, over time the entry and exit of liner companies should regulate the level of profit ensuring an adequate, but not excessive, return to efficient companies. That, at least, is the theory.

CASE 2: FIXED PRICES

The alternative strategy is for liner companies to fix prices at a level which gives a reasonable margin over average cost. We see the consequences of this approach in

Figure 13.14 which has the same demand and supply curves. Suppose the company decides to impose a fixed price of $1,250 per TEU, shown by the dotted line. During the recession at a price of $1,250 per TEU demand falls to about 3,250 TEU (see the intercept between D1 and the fixed price curve). At this cargo volume the average cost is $1,350 per TEU, so the company makes a loss of $100 per TEU or $0.3 million on the voyage. During the boom (D2) at a price of $1,250 per TEU demand rises to 4,250 TEU (see the intercept between D2 and the price curve). Since the ship can only carry 4,000 TEU at an average cost of $1,150 per TEU, the voyage makes a profit of $100 per TEU or $0.4 million on the voyage. Thus at this price of $1,250 the company makes a net profit of $0.1 million on the two voyages, which is not as much as they would have made under the marginal cost pricing case. It seems they misjudged the price they should fix.

If the fixed prices are judged correctly and strictly maintained, this policy offers a practical way of stabilizing cashflow. The company makes a smaller loss during the recession and a smaller profit during the boom. Compared with the free market case, the cashflow cycles are reduced and customers have the benefit of stable prices. If there is free entry to the trade, the company does not end up making excess profits because new firms enter and existing firms expand capacity, wiping out the excess profits.

This is the positive side of price fixing. Making it work is an economist's nightmare. Fixed prices can only work if most shipowners comply with the policy, but during a recession with prices way above marginal cost, individual companies have a tremendous incentive to drop their prices and fill their own ships. Thus the 'price ring' is under continuous pressure. Even worse, during the boom there is a risk that outsiders will pile into the trade, soaking up the premium cargo at profitable prices, and the charter market for container-ships has made this much easier. If strict discipline cannot be enforced, the cartel is squeezed in both directions. Because each route is just a small island in a sea of liner capacity, efforts to enforce discipline from within or without are easily frustrated.

A simplified example illustrates the problem. Suppose there are three ships in a service, two in a conference (i.e. cartel) and the third an 'outsider'. Trade is depressed with only enough cargo to load 3,250 TEU per ship, and this demand level is fixed, that is, not price sensitive. If the conference holds, each ship charges a fixed price of $1,250 per TEU and loads 3,250 TEU, making a small loss of $100 per container on the voyage. If, however, the outsider offers a price of $1150 per TEU, the whole picture changes. At this price he will win enough cargo to fill his 4,000 TEU ship, so his average cost falls to $1,150 per container and he breaks even. But the conference members are left with only 2,875 TEU each (i.e. there is potentially 9,750 TEU cargo and the outsider takes 4,000 TEU, leaving 5,750 TEU for the two conference ships to share). With only 2,875 TEU per ship their average cost increases to $1,450 per TEU, but the rate is now $1,150 per TEU, so they lose $300 per TEU. They have been mugged by the outsider and there is nothing they can do about it. The examples we have considered so far relate to market cycles. Exactly the same principles apply to seasonal cycles or trade imbalances. This is a good example of a situation known in game theory as the Prisoner's Dilemma.[44]

CASE 3: PRICE DISCRIMINATION

The third pricing option is *price discrimination*. One of the benefits of marginal cost pricing is that flexible prices help to coordinate cargo volume with the available capacity. Thus the low price during the recession in Figure 13.13 draws in marginal cargoes such as waste paper, hay or building-blocks, helping to fill up empty ships and generate extra revenue. As a result the cargo volume in the recession is 3,400 TEU compared with only 3,250 when the price is fixed at $1,250 per TEU. Conversely, during booms, high prices discourage cargo that will not bear the high freight rates, and the scarce capacity is taken by priority cargo, whereas the fixed price leaves the liner company with demand for 4,250 TEU, but only 4,000 slots. From this viewpoint flexible prices bring a positive benefit to the shipper and the liner company. One way to get the best of both worlds is to offer different prices for each commodity. Economists refer to this approach as price discrimination, and it is widely used in the transport system (e.g. business class versus economy class on the airlines). Low-value cargoes are offered cheap transport to fill empty capacity, while higher-value cargoes are charged a premium. Commodity price discrimination was widely used by cargo liner companies, though it has become more difficult since containerization has standardized the physical cargo. This aspect of pricing is particularly relevant to the containerization of minor bulk cargoes. Price discrimination can also be applied to customers. For example, special rates may be offered to customers who have large volumes of cargo. With all price discrimination the key is ensuring that the marginal revenue obtained from the cargo fully compensates the company for the cost of the service, including such hidden costs as repositioning containers. This is known as 'yield management'.

CASE 4: SERVICE CONTRACTS

As containerization reduced the opportunities for price discrimination, a fourth pricing option emerged, the service contract. This approach builds on the fact that large shippers have as much interest in stability as the liner companies and uses a negotiated service contracts to fix price and volume guidelines. Initially this approach raised anti-trust issues, especially in the US trades, but the US Ocean Shipping Reform Act (1999) gave shippers the right to confidential service agreements and private shipper service contracts were widely adopted. However, a survey published three years later suggested that the level of definition of these contracts is generally very low. Only 44% of the respondents had a formal freight contract, the rest relying on informal arrangements and 'referring to conference [general rate increases] in various trades, instead of setting a rate for the movement of containers from A to B'.[45]

13.10 LINER CONFERENCES AND COOPERATIVE AGREEMENTS

The economic analysis in the previous section suggests that the managers of liner companies are 'between a rock and a hard place' in trying to meet the varying needs of a diverse customer base whilst operating regular schedules with relatively inflexible strings of ships and at the same time cover a sizeable administrative overhead. In free market trade cycles, seasonal cycles and trade imbalances produce volatile revenues. Living with a volatile cashflow is not particularly attractive and since they are in a position to form cartels this is an obvious strategy. As we have seen, efforts to take over from the market and 'manage' prices or capacity present great problems. But Figure 13.14 showed why economic forces do not favour stable liner price cartels. Companies which break the price ring reap such handsome profits at the expense of the cartel members that restraint never lasts long, especially in the age of containerization. With bank managers to pay, shareholder pressure for higher returns, or a government sponsor keen to see its domestic shipping company take a bigger share of the trade, there are too many temptations. In an industry where the barriers to entry are low, rate stability must be the exception rather than the rule.

Despite these difficulties, the quest continues. Over the years managers in the liner business have come up with a bewildering array of solutions. Some have concentrated on the revenue side, seeking to fix prices for the whole trade, often supported by a complex arrangement of loyalty rebates, commodity discounts, service agreements offering special rates to major clients, and other devices designed to blend fixed pricing with a degree of flexibility. Others have tackled capacity, attempting to strike at the root of the problem by fixing trade shares so that companies cannot compete for each other's cargo. From time to time there have been inter-company agreements to share shipping space and increase flexibility. Some major companies prefer independence and the free market, but one way or another most end up seeking ways to restrict market forces. In the next section we discuss these arrangements. Because they are constantly changing they are not easy to analyse or classify. We briefly review their history, more as an illustration of what can happen than as a definitive account of the system.

Liner conferences

The *conference system*, which was developed in the mid-1870s, was the industry's first attempt to deal with the pricing problem. The major British shipping companies such as P&O, Alfred Holt and Glen Line, which set up the first liner services to the Far East in the early 1870s, found that, from the outset, competition was forcing tariffs to levels that would not cover their average costs. They faced all the problems mentioned in the previous section. There was overcapacity due to overbuilding; the trades were highly seasonal, particularly in agricultural products such as tea, so for part of the year the ships were only half full; and there was also an imbalance between the east-bound and the west-bound trade with the demand for shipping space to China falling short of the demand from China.[46] As a result, there was often more shipping capacity than cargo. Of course none of this was new. What had changed was the organization of the business. Because the newly emerging liner companies were operating in the same trades they were in a much better position to form a cartel to fix rates so that, in the words of John Swire, 'the companies may not ruin each other'.[47]

The first conference was formed in August 1875 by the lines trading between the United Kingdom and Calcutta. It was agreed to charge similar rates, to limit the number of sailings, to grant no preferences or concessions to any shippers and to sail on a given date regardless of whether they had a full load of cargo.[48] However, because of the over-tonnaging situation, this simply resulted in the major shippers, particularly the powerful Manchester merchants, threatening to use vessels outside the conference that would offer lower rates.[49] A custom already existed that the charge made for the use of ship's gear in loading and unloading was remitted to merchants who shipped regularly with the same company. In 1877 the conference used this as the basis for a rebate system. A reduction in rates of 10% was made to merchants who shipped exclusively with the conference for a period of six months, but the rebate was not paid until a further six months had elapsed, during which time the loyalty rebate was forfeit if the merchant used a ship owned by a firm not a member of the conference.[50] This meant that any shipper tempted by the cut-price rates of non-conference operators stood to lose a very substantial sum if they accepted.

This was only the beginning. Over the next century there was a constantly evolving network of agreements covering rates, the number of sailings, the ports served, the goods carried, and the sharing of freight revenues ('pool' agreements). *Closed* conferences control membership, share cargo and use price discrimination to encourage the major shippers to ship exclusively with the conference. For example, regular shippers might be charged a lower 'contract' rate, with a higher rate for shippers who sometimes used outsiders. The 'deferred rebate' developed in the Calcutta trade was also used. Loyal shippers receive a cash rebate, say 9.5%. *Open* conferences allow any company to join provided they comply with the rate agreements. Members are thus guaranteed the prices set by the conference but, since there is no control on the number of ships in service, open conferences are more vulnerable to over-tonnaging. By the early 1970s there were more than 360 conferences with membership varying from two to 40 shipping lines[51] and thirty years later in 2002, despite the inroads made by containerization, there were still 150 liner conferences operating world-wide, again with membership ranging from two to as many as 40 separate lines.[52]

However, the market changes which accompanied containerization, particularly the standardization of the market and global competition, weakened the industry's ability to enforce price cartels, and regulatory authorities have become less sympathetic to the arguments for exempting conferences from anti-trust legislation. As a result attention switched to strategies for reducing unit costs through consortia, alliances, and mergers which are acceptable to the regulatory authorities. A discussion of these issues can be found in Section 16.12.

Global alliances

By the late 1980s the conference system had become seriously weakened,[53] and although efforts to resolve the pricing problem continued as actively as a century earlier, to the general disapproval of regulatory authorities, the industry changed its strategy. On the Pacific route a series of stabilization agreements were developed, no longer called conferences, the first being the Trans Pacific Discussion Agreement (TPDA). On the Atlantic the Trans Atlantic Agreement (TAA) subsequently became the

Trans Atlantic Conference Agreement (TACA). In the mid-1990s about 60% of the liner capacity on the major routes belonged to this sort of conference system, though the modern open conferences are very different from the tightly controlled closed conferences of the 1950s. Some act mainly as secretariats to the trades, administering rate agreements and dealing with the various regulatory bodies. In 2007 the two main conferences were the TSA (Transpacific Stabilisation Agreement) and the FEFC (Far East Freight Conference), but there were still many conferences covering smaller trades.

These arrangements, which we have already discussed in Section 13.6, are in many ways the industry's response to the changing requirements of containerized liner services. Unlike the old liner system which focused on individual routes, today competition is global and some of the larger companies develop alliances under which the members continue to run their own commercial operations, whilst sharing the management of services and container deployment. The Alliance agreements generally cover three main areas. Firstly, the service schedules including the type and size of vessel to be employed on each route; itineraries and sailing schedules; and ports and port rotations. Secondly, the various support services including chartering of ships; use of joint terminals; the management of containers; feeder services and the coordination of inland services. Thirdly, there may be restrictions on the activities of members such as the use of third-party carriers on specific routes subject to the consent of members and measures for capacity to deal with shortages and surpluses. This allows the members to use their combined size to improve the efficiency of global operations. The agreements do not generally cover sales, marketing or pricing, which are left to the individual members, as are invoicing and bills of lading. Ships continue to be owned and operated by the member companies which retain their own individual management functions.

Principles for regulating liner competition

Since the beginning of liner services in the 1870s there has always been criticism of conferences by shippers' organizations, but a degree of cooperation between carriers was tolerated. There were several reasons for this, and a detailed study of liner shipping competition by the OECD in 2001 examined the economic evidence. It concluded that the underlying economics of the liner business were not fundamentally different from other transport sectors and that in fact the industry had become more competitive as conference power weakened and carriers turned to more flexible alliances aimed at gaining greater operational efficiency.[54] As a framework for designing the best solution they identified three issues:

- Freedom to negotiate. Rates, surcharges and other terms of carriage in liner shipping should be freely negotiated between shippers and carriers on an individual and confidential basis.
- Freedom to protect contracts. Carriers and shippers should be able to contractually protect key terms in negotiated service contracts including information regarding rates.

- Freedom to coordinate operations. Carriers should be able to pursue operational agreements with other carriers so long as these do not include price fixing or conferring market power on the parties involved.

If followed, these principles would, they argued, help to establish the right and equitable balance between the market power of shippers and shipowners. The regulation of liner shipping is discussed in Section 16.10.

In October 2008 the EU's repeal of regulation 4056/86 which removed the liner industry's block exemption from Articles 81 and 82 of the Treaty of Rome will take effect and conferences will be subject to these regulations. This change in the regulations governing liner services operating in and out of the EU will have a major impact on conferences such as the Far East Freight Conference. The regulatory issues are discussed in Section 16.10.

13.11 CONTAINER PORTS AND TERMINALS

Port calls and liner pricing

Containerization changed the way the liner business managed its port itineraries. Previously cargo liners operated a port-to-port service, 'equalizing' prices by charging the same rate for all ports on their itinerary. Because shippers paid for the journey to and from the port they had an incentive to use a liner service which called at the local port. Each port had its own catchment area and to win a share of this cargo, liner services had to include that port on their itinerary. This pricing system encouraged lengthy itineraries and much duplication of port calls.

When containerization was introduced, the pricing system changed. Because the liner companies gained control of the land transport they could plan and adopt the itinerary which gave the cheapest overall unit transport cost. The result was to channel trade through fewer ports, each major port having a greatly enlarged catchment area. It also led to new competition between the ports to attract liner services. Choosing a port itinerary involves a trade-off between the cost of the call and the revenue obtained from providing a direct service to and from the port. Then there is the possibility of setting up intermediate distribution points to serve a third area. For example, the Arabian Gulf might be served by a feeder service from Jeddah in the Red Sea. In fact, we can define two levels of service:[55]

- *Load centres (base ports)*. These have a regular service with frequent loading and discharge of cargoes. The shipper is guaranteed a regular service at a fixed tariff, whether they are served directly or not. For example, Antwerp will attract the same rate as Rotterdam, even if the ship does not call there.
- *Feeder ports (outports)*. Some ports are not included in the normal service because they do not handle sufficient cargo to make this cost-effective. However, in order to

discharge their obligation to 'meet the requirements of the trade', the company accepts cargo at outports and provides a feeder service to a base port. These cargoes will be charged extra.

The port infrastructure

Although there are currently about 400 ports which have a significant throughput of containers, the top 60 handle 98% of the throughput. Many countries now have only one or two major container ports serving the deep-sea trades, supported by a range of smaller ports handling short-sea and distribution trade. Table 13.10 lists the 36 most important container ports in 2005, organized by region. Between them these ports handled 194 million TEU in 2005, about 60% of the total container lifts, and between 1994 and 2005 their trade grew at 9.4% per annum. Interestingly the Middle East grew fastest with 13.4% growth per annum, followed by Asia at 9.6%, Europe slightly more slowly at 9.1% and North America fourth at 8.9%. The two largest container ports, Hong Kong and Singapore, each handled over 20 million TEU in 2005, acting as regional distribution centres for the predominantly maritime Asian distribution system. Shanghai was catching up fast and showed the fastest cargo growth of any port over the decade.

Container terminals generally have several berths, each served by one or more large cranes capable of lifting 40 tons. In an adjacent storage area the containers are stored to await collection. To carry the weight of the container crane it is generally necessary to strengthen the quay to support the container cranes. Several types of container terminal have been developed to meet differing requirements. One system is to lift the container off the ship on to a trailer chassis, which is then moved to a storage park to await collection. This has the advantage that the container is handled only once and it interfaces efficiently with the road haulage system. Its main drawback is that it uses a large amount of land and there is a significant investment in trailers. Where land is at a premium, containers could be stacked up to five high, using a system of gantry cranes which may also be used on the quayside, but the disadvantages of this system are the difficulty of obtaining random access to containers in the stack and the cost of multiple handling of individual units. The compromise is to stack containers two or three high, using 'straddle carriers', large fork-lift trucks or low loaders to move them from the quayside to the stack and retrieve them when required. In small ports an area of the quayside is often allocated for container storage.

In the advanced industrial areas of Europe, North America and the Far East, containerization has channelled trade through a small number of ports that have invested in high-productivity container terminals of the type outlined above. In the developing countries the problem is more complex, since the inland infrastructure is often not sufficiently developed to handle a sophisticated container network. As we saw in the example of the West Africa trade, cargo is not exclusively containerized. In such cases, even small ports need to be equipped to handle containers. This generally involves developing an existing berth for container handling, undertaking any necessary strengthening of the quay, the purchase of a suitable crane, often a mobile unit, and

Table 13.10 Container traffic of 36 major ports, 1994 and 2005

World rank 2005	Country		Traffic (lifts) M TEU 1994	2005	% pa	Region
	Asia					
1	Singapore	Singapore	9.0	23.2	8.6%	Asia
2	Hong Kong	Hong Kong	9.2	22.4	8.1%	Asia
3	Shanghai	PRC	0.9	18.1	27.3%	Asia
4	Busan	S. Korea	3.1	11.8	12.2%	Asia
5	Kaohsiung	Taiwan	4.6	9.5	6.5%	Asia
12	Port Kelang	Malaysia	0.8	5.5	17.9%	Asia
15	Tokyo	Japan	1.5	3.6	7.7%	Asia
16	Tanjung Priok	Indonesia	1.0	3.3	10.8%	Asia
18	Yokohama	Japan	2.2	2.9	2.6%	Asia
21	Manila	Phillipines	1.3	2.7	6.8%	Asia
22	Colombo	Sri Lanka	0.9	2.5	9.6%	Asia
23	Nagoya	Japan	1.2	2.3	6.3%	Asia
25	Kobe	Japan	2.7	2.3	-1.5%	Asia
27	Keelung	Taiwan	1.9	2.1	1.1%	Asia
33	Bangkok	Thailand	1.3	1.3	0.6%	Asia
	Total Asia		41.3	113.4	9.2%	
	W. Europe					
6	Rotterdam	Netherlands	4.2	9.3	7.6%	Europe
7	Hamburg	Germany	2.5	8.1	11.3%	Europe
11	Antwerp	Belgium	1.9	6.5	11.9%	Europe
14	Bremerhaven	Germany	1.4	3.7	9.7%	Europe
17	Algeciras	Spain	0.8	3.2	13.2%	Europe
20	Felixstowe	UK	1.6	2.7	4.6%	Europe
26	Le Havre	France	0.9	2.1	8.1%	Europe
36	La Spezia	Italy	0.8	1.0	2.5%	Europe
	Total Europe		14.0	36.6	9.1%	
	Middle East					
8	Dubai	UAE	1.7	7.6	14.7%	Middle East
19	Jeddah	Saudi Arabia	0.9	2.9	10.6%	Middle East
	Total Middle East		2.6	10.5	13.4%	
	North America					
9	Los Angeles	USA	2.4	7.5	11.0%	N.America
10	Long Beach	USA	2.1	6.7	11.3%	N.America
13	New York	USA	2.0	4.8	8.4%	N.America
24	Oakland	USA	1.3	2.3	5.2%	N.America
28	Seattle	USA	1.2	2.1	5.6%	N.America
29	Tacoma	USA	1.1	2.1	6.2%	N.America
30	Charleston	USA	0.8	2.0	8.1%	N.America
31	Hampton Roads	USA	0.8	2.0	8.8%	N.America
	Total N. America		11.6	29.4	8.9%	
	Other					
32	Melbourne	Australia	0.7	1.9	9.3%	Oceania
34	San Juan	Puerto Rico	1.6	1.3	–1.8%	S. America
35	Honolulu	USA	0.7	1.1	3.5%	N.America
	Total container lifts by 36 ports		72.5	194.0	9.4%	

Source: CRSL, *Containerisation International* straddle carriers or fork-lift trucks and the provision of a container-packing service for break-bulk cargo not delivered to the port in a container. The containers are then stacked in a suitable location.

13.12 SUMMARY

As we have seen in this chapter, liner companies carry ‘general cargo’ and operate in a market which has all the competitive edge of the bulk shipping market, but with two major differences which alter the market and the competitive process. First, the need to run a regular service makes liner capacity inflexible. Second, with so many customers, price negotiation is more restricted. With these restrictions the free market mechanism which regulates the bulk shipping market takes on a very different character in the liner business. When we examine the economic principles, we find that free market pricing would lead to a highly volatile cashflow, but that a system of fixed prices is difficult to enforce. That, in essence, has been the problem faced by the liner industry throughout its 125-year history.

Our review of the evolution of the liner business demonstrated the changes containerization has brought to the business, and we examined the global market model which now provides the framework for trade. This network of services is constantly changing to meet the needs of trade. The major liner routes, known as the East–West trades, operate between the three industrial centres of North America, western Europe and Asia. These are supplemented by a complex matrix of North–South trades serving the various developing countries. At the margin are the small services designed to meet particular local needs. A highly flexible supply system has evolved to service these trades involving alliances, space chartering arrangements and a charter market for the ships which grew from almost nothing in the early 1990s to over half the capacity in 2006.

Our review of the demand for liner services concluded that the ‘commodity analysis’ used to analyse the demand for bulk carriers is less appropriate as a methodology for the liner trades. There are so many commodities and so few statistics that detailed commodity analysis can hardly be expected to succeed. More importantly, the demand for liner transport is not determined by regional imbalances in supply and demand, but by the relative price and availability of goods. If a manufacturer in England can source more cheaply from Taiwan than from Scotland, he will choose Taiwan. In this sense the growth of demand depends on cost differences within the world economy, while inter-company competition revolves around a range of factors including price, speed, reliability and the quality of service.

The general cargo trade is carried by a fleet of ships comprising container ships, MPP vessels, ’tweendeckers, traditional cargo liners and ro-ros. Some of these vessels are designed to meet specific trading needs, while others are left over from another shipping era, serving out their useful lives. The whole liner business is supported by an extensive network of port facilities, ranging from the ‘super-terminals’ in Rotterdam, Hong Kong and Singapore to the many minor local ports which serve the feeder trades.

We examined the structure of liner costs and identified eight ‘building-blocks’ which contribute to the economics of a liner service: the ship characteristics, the service schedule, capacity utilization, ship cost per day, port charges, deployment of containers, container costs and administrative costs. The choices made by the liner company for each of these determines the cost profile of the operation. On the revenue side, the key principles are price stability and price discrimination. The pricing system, which involves differing degrees of discrimination by commodity and owner, has now been substantially modified by the widespread use of service contracts negotiated bilaterally between carriers and shippers.

The lessons from the liner business are simple enough. By using containers to mechanize the transport of general cargo, it has, in Adam Smith's words 'opened the whole world to a market for the produce of every sort of labour'. The financial return to liner companies may not be spectacular, but their contribution to the global trading economy is beyond question.

Part 5

THE MERCHANT FLEET AND TRANSPORT SUPPLY

14 The Ships that Provide the Transport

Managers may believe that industry structures are ordained by the Good Lord, but they can – and often do – change overnight. Such changes create tremendous opportunities for innovation.

(Peter Drucker, *The Profession of Management*, 1998, p. 58)

14.1 WHAT TYPE OF SHIP?

The derived demand for ships

So far we have said much about shipping economics, but little about the ships themselves. A ship is a major investment, and with a wealth of different types and sizes on offer, investors are confronted with the difficult question of what type of ship to order. To help them in their decisions, they often ask shipping economists what will be the future demand, for example, for container-ships. The aim of this chapter is to discuss the different types of merchant ships and how their design features fit into the economic model discussed in Chapter 4.

First we must be clear about the meaning of *demand*. Although ships occupy centre stage, the product in demand is not a ship, but transport. It is not the container-ship that the customer wants; it is the transport of the container. Shipowners can use whatever ships provide the transport most profitably. Unfortunately this makes the shipping economist's job much more difficult. If containers could only be carried in container-ships, all the shipping economist would have to do is predict the trade in containers and work out the number of container-ships needed to carry the trade. But with several ship types available to carry the cargo which travels in containers, the demand calculation involves two additional questions. What options are open to the shipowner? And what economic criteria apply in choosing between them?

The answer depends on the type of shipping venture for which the vessel is intended. Although there are many different influences to consider, the most important can be summarized under the three following headings:

- *Cargo type*. The physical and commercial properties of the cargo to be transported set a limit on the ship types that can potentially be employed in the transport operation.

In a limited number of cases, such as liquid natural gas or nuclear waste, the cargo demands a specific type of ship, and the shipowner's choice is limited to general design and operating features such as speed and crew. For most cargoes, however, the shipowner can choose from several ship types. Crude oil can be carried in a specialist tanker or a combined carrier; dry bulk can be carried in a conventional bulk carrier, an open-hold bulk carrier or a combined carrier; containers in a container-ship, a 'tweendecker, an MPP vessel or a ro-ro.

- *Type of shipping operation*. In the previous paragraph we assumed that the shipowner knows the precise type of cargo to be carried, but in practice his knowledge of both the cargo and other physical operating constraints will depend upon the type of shipping operation for which the vessel is intended. There are several different types of shipping operation, for example: *long-term charters*, where the shipowner has some knowledge from the charterer of the cargoes to be carried and the ports to be used; *spot charter market operations*, where the owner has only a general idea of the type of cargo to be carried and no knowledge of the ports to be visited; and *liner operations*, where the owner has a specific knowledge of the ports to be visited and the likely cargo volume, but where both may change during the operational life of the vessel. The design criteria for a shipowner choosing a vessel for a long-term time charter are likely to be quite different from those for the owner intending to trade on the spot market. For example, the former will be preoccupied with optimizing the ship to a specific operation, whereas the latter will be more concerned with such factors as the vessel's acceptability to charterers, and its short-term resale value.
- *Commercial philosophy*. The way in which the shipowner or shipping company approaches the business may extend or limit the range of options. For example, one shipping company may prefer vessels that are highly flexible, servicing a number of different markets and thereby reducing the risk. This philosophy might lead the shipowner to prefer a more expensive open-hold bulk carrier, which can carry both dry bulk cargo and containers. Another owner may follow a policy of specialization, preferring a vessel that is in every respect designed for the efficient carriage of a single cargo, offering greater efficiency or lower costs but at the price of less flexibility.

It follows that shipping economists cannot forecast the demand for a particular type of ship just by studying cargo movements. In the real world the choice of a particular ship type depends on all three factors – cargo type, shipping operation and commercial philosophy. This makes it difficult to predict which factors will predominate in the final decision. Market research techniques of the type discussed in Chapter 17 will certainly form part of this process, as will fashion and market sentiment.

The fleet by ship type

Since few ships are truly identical, one problem in discussing ship design is the sheer number of vessels involved.[1] So our first task is to classify the designs into types with common features, which we do in Figure 14.1. The world's 74,398 maritime vessels (Table 2.5) are first divided into the three groups of structures operating on the oceans: cargo shipping (group 1), offshore oil and gas structures (group 2) and non-cargo ships (group 3). Cargo ships, our main focus here, are split into four sectors based on economic activity: general cargo transport; dry bulk transport; oil and chemical transport; and liquid gas transport. At the third level the merchant ship sectors are divided into 19 ship types based on the physical design of the hull: for example, tankers have tanks, bulk carriers have holds and vehicle carriers have multiple decks designed to carry as many cars as possible. If this were a technical book we would probably stop there, but as economists we must recognize a fourth level of segmentation by ship size. Size restrictions on terminal facilities and waterways such as the Panama Canal divide ships of a particular type into segments.

This chapter is organized around the four sectors of the merchant fleet which transport general cargo, dry bulk, oil and chemicals, liquid gas, with a short section on non-cargo carrying vessels (see Figure 14.1). There are seven general cargo types, six dry bulk types, four oil and chemical types, two liquid gas types and four non-cargo types. Looking over this figure and Table 14.1, which shows how 19 segments of the fleet grew between 1990 and 2006 gives a sense of the way the ship type structure of the fleet is constantly changing. Between 1990 and 2006 the world fleet grew at an average of 2.7%

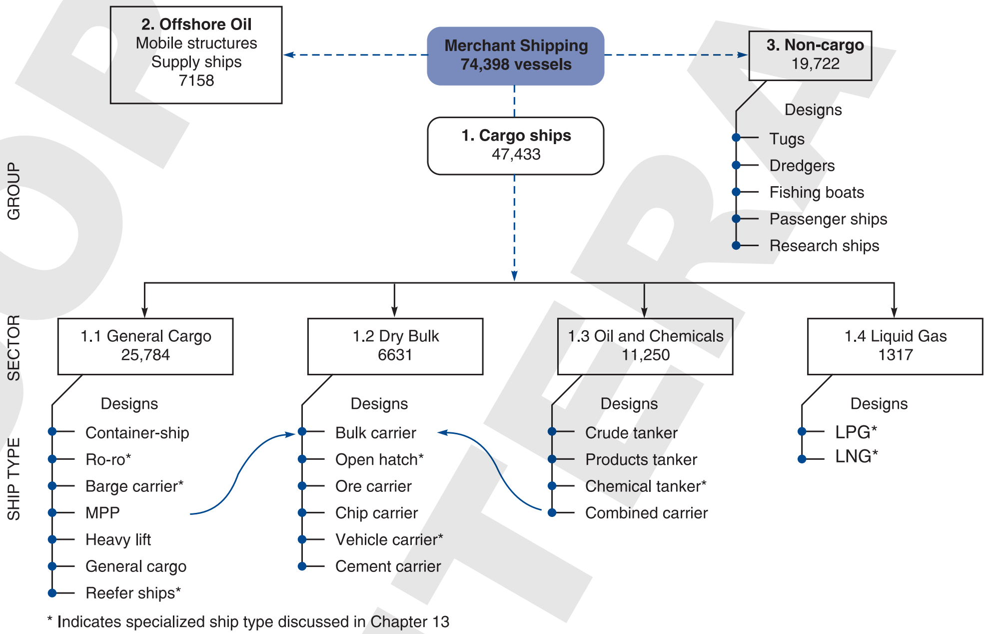


Figure 14.1
The commercial shipping fleet, 1 July 2007, classified by group, sector and ship type
Source: Ship numbers from Table 2.5

Table 14.1 World cargo fleet showing growth rates 1990–2006 of 19 ship type segments

		No.	Design Start	Fleet m.dwt 1990[a]	Fleet m.dwt 2006	Number 2006	Growth 1990–2006[b]	Key design issues
1. General cargo	Container	1	100–999 TEU	5	9	1,167	4.2%	Slow, geared
	Container		1,000–2,999 TEU	17	41	1,659	5.8%	Faster, some geared
	Container		3,000 + TEU	4	61	1,113	18.0%	Fast (25 kts), no gear
	Container		Total container	26	111	3,939	9.4%	
		2	Ro-ro	7	9	1,109	2.1%	Ramp access to holds
		3	MPP	17	23	2,533	2.0%	Open hatch, cargo gear
		6	Heavy lift	—	1	53		53 ships, excludes MMPs
		4	Barge carriers			6		
		5	Gen. cargo	27	11	1,024	–5.3%	Includes liner types and tramps
		7	Reefer	7	7	1,237	–0.1%	Refrigerated, palletized
			Total liner	84	163	9,901	4.2%	
2. Dry Bulk	Bulk carrier	8	Capesize	48	111	703	5.4%	Carry ore and coal
	Bulk carrier		Panamax	43	94	1,386	5.1%	Coal, grain, few geared
	Bulk carrier		Handymax	31	67	1,488	5.0%	Workhorse, mainly geared
	Bulk carrier		Handy	82	74	2,762	–0.7%	Smaller workhorse
	of which:	9	Open hatch	—	17	481		Designed for unit loads
		10	Ore carrier	9	9	51	–0.4%	Low cubic (0.6 m^3/tonne))
		11	Chip carrier	—	6	129		High cubic (2 m^3/tonne)
		12	Vehicle carrier	4	8	594	4.2%	Multiple decks
		13	Cement carrier			77		
			Total dry bulk	203	345	6,339	3.4%	
3. Liquid Bulk	Crude	14	VLCC	114	143	483	1.4%	Long-haul crude oil
	Crude		Suezmax	35	54	350	2.8%	Medium-haul crude
	Crude		Aframax	38	73	705	4.2%	Some carry products
	Crude		Panamax	14	23	305	3.0%	Very short haul
	Crude		Handy	50	76	2,414	2.6%	Mainly products
	Crude		Total oil	243	368	4,257	2.6%	
	of which:	15	Products tanker		49	1,196		Some overlap with chemicals
		16	Specialized tanker	10	41	2,517	9.1%	More tanks and pumps
		17	Oil/bulk/ore	32	10	95	–7.2%	dry and wet
		18	LPG	7	11	1,030	3.2%	Several freezing systems
		19	LNG	4	17.5	222	9.3%	–161°C
World Fleet				573.1	914.7		2.9%	

[a]Container-ship dwt 1990 estimated from TEU statistics

[b]To show the growth rate since 1990 it was necessary to use slightly different statistical groupings from those shown in Figure 14.1 and Table 2.5.

Source: Clarkson Registers April 2006 and Shipping Review and Outlook Spring 2007, CRS, London

per annum, but the growth rate differed significantly between segments. The container-ship fleet averaged 9.4% per annum whilst the general cargo fleet declined at 5.3% per annum, so the liner fleet as a whole averaged 4.2% growth. In the bulk carrier segment the bigger sizes grew at about 5% per annum whilst the fleets of small bulk carriers and ore carriers both declined, so the dry bulk fleet averaged 3.4%. The tanker fleet grew even more slowly, averaging 2.6% per annum, with Aframax tankers showing the fastest growth and the VLCC fleet the slowest. The specialized fleets all grew at very different rates, with LNG tankers expanding fastest and the reefer fleet declining. All of which demonstrates the dynamic way the fleet structure evolves over time in response to the changing trade flows. This makes selecting the right type even more tricky.

14.2 SEVEN QUESTIONS THAT DEFINE A DESIGN

Broadly speaking, each ship is a bundle of features blended to achieve a specific objective, but, for the reasons discussed in the last section, the design parameters are not always clear-cut and designing a ship is not a precise science that can be reduced to purely economic criteria. Benford develops this point in the following way:

> Whether we use computers, hand held calculators, or backs of envelopes one rule applies: the decision will be made by some person, or group of persons, and will not hinge simply on the best numerical projection of some measure of merit. Like nearly all else in our business, there is art as well as science in this. Indeed – and roughly speaking – the more important the decision the greater is the reliance upon art. That is what makes ship design so fascinating.[2]

On this theme, before looking at individual ship types, it is helpful to review seven questions analysts should ask when defining the particular bundle of features the investor needs.

How will the ship be traded?

The first question to ask is why the investor wants the ship. There may be lots of clever technology available which naval architects can use to produce the perfect ship, but investors have their own objectives. For example, they often value simplicity and robustness over technical perfection, in which case designing their ships is about optimizing commercial rather than technical performance. Clever and innovative technical designs make great conference papers but have a patchy history in the practical world of commercial shipping.

Anyway, investors often have only a rough idea about the type of cargo to be carried. If there is a *long-term charter* the shipowner probably knows the likely cargoes to be carried and possibly the ports to be used, but if the ship is to trade on the *spot market* there will be only a general idea of the type of cargo to be carried and no knowledge of the ports to be visited. In this case the investor is more interested in such factors as the vessel's acceptability to charterers and its short-term resale value. Ships built for *liner services* can often be designed for the particular route and tailored in such areas as reefer capacity, but these things change during the operational life of the vessel and container-ships are increasingly commoditized. The following examples illustrate some of the different angles from which investors may approach commissioning a new ship:

Example 1. A steel plant purchasing an iron ore carrier to service a long-term iron ore supply contract between Brazil and China. In this case, the cargo, the cargo volume and the trade route are all known in advance, and the ship will be dedicated to the trade over its life, so the design can be optimized to the shipping operation in terms of the cargo to be carried, the parcel size, the ports to be utilized and the opportunities for exploiting economies of scale. In addition, since the vessel is to be operated over a number of years, the shipowner is likely to take a close interest in any technology that will reduce operating costs – for example, automation and fuel-saving equipment.

Example 2. A dry bulk carrier operator purchasing a bulk carrier to trade on the voyage charter market. In this case, the shipowner has only a general idea of the cargoes and ports that the vessel will be required to service. Depending upon his style of operation, he may choose a small ship that can access many ports, or a larger ship that will be more competitive in some of the major bulk commodity trades. In particular, he wants the ship to be attractive to charterers, with a good resale value even after a short time. For this reason, a well-established standard design may be of interest and design features such as fuel saving equipment will only be of interest if they add to the ship's value in the second-hand market, which many do not.

Example 3. A company planning investment in a specialist bulk market such as motor vehicles or forest products may not have a precise future operating pattern, but will know what cargo features are needed to reduce operating costs and improve the service. This may lead to the design of a completely different type of ship such as a vehicle carrier, or a sophisticated version of a standard ship such as a forest products carrier. In such cases, the cargo figures prominently in the ship design, as do the range of ports, terminals and cargo-handling facilities servicing this particular trade.

Design sophistication comes at a price which makes it risky, and the preceding examples illustrate that investors have different requirements which determine how closely the ship is optimized to a particular cargo or trade route.

What cargo will the ship carry?

Cargoes come in all shapes and sizes. Some, like grain, are homogeneous whilst others, such as logs or steel products, consist of large regular or irregular units that present the ship designer with a different challenge. This is not just about the commodity, because the same commodity can be transported in many different ways. For example, china clay can be loaded into bags transported loose, on a pallet, or in a container; shipped loose in the hold of a bulk carrier; or mixed with water and shipped in a tanker as slurry. These are all examples of 'cargo units', the term used to describe the physical form in which a commodity is presented for transport, and 12 of the most common ones are summarized in Box 14.1.

In a few cases, such as LNG or nuclear waste, the cargo demands a specific type of ship, and the shipowner's choice is limited to general design and operating features such as size, speed and crew. For most cargoes, however, the shipowner can choose from several ship sizes and types. Crude oil is carried in different sizes of tanker or even a combined carrier; dry bulk can be carried in a conventional bulk carrier, an open hold bulk carrier or a combined carrier; containers principally move in different sizes of container-ship, but MPP vessels and ro-ros carry them as well. The first six items on

BOX 14.1 PHYSICAL UNITS IN WHICH COMMODITIES ARE SHIPPED BY SEA

Cargo unit	Comment/commodity
Natural cargoes:	
General cargo	Small parcels of loose items – e.g. boxes, bags, packing cases, drums, a few cars, machines.
Dry bulk cargo	Cargo in ship- or hold-sized parcels that can be handled in bulk by gravity/pump loading and grab/suction/pump and stowed in its natural form – e.g. oil, iron ore, coal, grain and cargo.
Liquid bulk cargo	Liquid bulks raise four issues: parcel size which can vary from a few thousand tons to 300,000 tons; density of the liquids transported varies; some liquids are corrosive; some liquids are considered hazardous by regulators and require special transport.
Unit bulk cargo	Large quantities of units that must be handled individually – e.g. logs, sawn lumber, steel products, bales of wool or wood pulp.
Heavy and awkward cargo	Heavy loads up to 2,500 tons – e.g. project cargo, modular industrial plant, ship sections, oilfield equipment, locomotives, yachts, shiploader cranes.
Wheeled bulk cargo	Cars, tractors, lorries, etc. shipped in large quantities.
Artificial units	
Containers (ISO)	Standard boxes usually 8′ wide × 8′6″ high in lengths of 20′ and 40′, with a 20′ box typically handling 7–15 tons of cargo, typically stowing at 2.5–5 m^3 per ton.
Intermediate Bulk Container	Large bags typically 45″ in diameter with capacity of around 1 tonne of granular material and designed for efficient mechanical stacking, handling and discharging.
Pre-slung or banded	Usually used for sacks, bales and forest products, to speed up loading and discharge. The slings are left in place during transit.
Palletized cargo	Cargo is stacked on a pallet and usually held in place by steel or plastic bands or ‘shrink fit’ plastic – e.g. cartons of fruit. Can be handled by fork-lift truck. Dozens of sizes up to 6′ × 4′. Palletized cargo stows at about 4 m^3/ton.
Flats	Normally about 15′ × 8′, often with corner posts to allow stacking two high. Handled by fork-lift or crane.
Barges	LASH barges load about 400 tons cargo and Seabee about 600 tons. The barges are designed to be floated to the ship and loaded/discharged as a unit. Never caught on and now obsolete.

the list are ‘natural’ cargo units, that is, the cargo is shipped in its natural form without pre-packing. General cargo consists of loose items such as bags or boxes, without any special packing. This type of cargo is the most difficult and expensive to transport by sea. Packing it into the hold of a ship is time-consuming, requires skill, and there are associated problems of loss and damage in transit, as was explained in Chapter 13.

A dry bulk cargo unit is a ship- or hold-size parcel of homogeneous cargo – for example, 150,000 tonnes of iron ore, 70,000 tonnes of coal, 30,000 tonnes of grain, 12,000 tonnes of sugar – whilst liquid bulk cargoes range in size from 500 tonnes of a chemical to 450,000 tonnes of crude oil. Homogeneous bulk cargoes can be loaded and unloaded using grabs or suction as appropriate, and the aim is generally to design a ship that can load its full cargo deadweight of a single commodity, though in some trades that does not always apply. For example, in oil products many ships carry cargo parcels that do not fully utilize the ship's deadweight, such as naphtha, and may be designed with this in mind. In practice, the hold is the smallest size unit for dry bulk cargo and the cargo tank the smallest unit for liquid bulk. Unit bulk cargoes consist of ship-sized parcels made up of units each of which must be handled individually – for example, steel products, forest products or bales of wool. In such cases it may be possible to design 'tailored' vessels offering improved stowage or faster cargo handling. Finally, the other natural cargo units are heavy and awkward cargoes and wheeled cargoes. Heavy and awkward cargoes are worth singling out because they present special shipping problems in terms of handling and stowing the cargo. For example, the tunnel kiln for a cement plant or a small warship being shipped from Europe to the Far East both present stowage problems.

The remainder of Box 14.1 is concerned with cargo that is pre-packed for transport, usually so that it can be handled mechanically rather than requiring skilled manual handling and stowage. Standardization also allows cargo units to be moved seamlessly between rail, road and sea vehicles, improving the efficiency of integrated 'door-to-door' transport services. In practice, there are six main forms of artificial cargo units: containers; intermediate bulk containers; pre-slung or banded; pallets; flats; and the now little-used barges.

By far the most important artificial unit is the *ISO container*. Standard 20 ft and 40 ft containers give the shipowner a homogeneous cargo that allows mechanized loading and discharging systems and produces a major improvement in efficiency. However, the uncompromising size, shape and weight of the container box presents designers with a specific set of problems.

Intermediate bulk containers are large bags made of flexible fabric, designed for mechanical filling, handling and unloading of solid materials in powder, flake, or granular form. They were first manufactured in the late 1950s and are mainly used for minor bulks such as chemicals and high-value ores.

The use of *pallets* and *flats* provides a degree of unitization without requiring the high capital costs incurred by containers and trailers, and there are fewer problems in returning the empty units. Pallets have not become established as a base unit for a sea transport system in the same way as containers except on individual routes where they meet a special need, for example in the refrigerated cargo trade. The cargo is loaded on to a pallet, of which there are a variety of sizes, and secured with bands or a plastic cover shrunk to protect the cargo. Loading and discharge are still labour-intensive operations and rely on the skill of stevedores to pack the pallets into the ship efficiently. It is, however, dramatically more efficient than the handling of individual boxes, drums, sacks or bales. Finally, *barges* were introduced in the 1960s in an attempt to cater for the small bulk packages of medium-value cargoes, especially where an inland waterway system allows through water transport to inland destinations, but were never widely adopted.

How should the cargo be stowed?

The next issue is how best to tailor the cargo spaces to fit the cargo units the ship will carry. This presents more difficult choices because optimizing stowage often has adverse consequences for other aspects of the design. Buxton describes the problem in the following way:

> Merchant ships are mobile warehouses whose many different forms have evolved as a result of attempts to balance on the one hand the need for suitable storage capacity, against on the other hand the need for mobility. Thus a ship constructed as a simple rectangular box of appropriate dimensions could provide an ideal space for storing containers, but would be difficult to propel through the water, while an easily driven hull would offer relatively little useable cargo space. Ship design is largely a matter of solving such conflicts to produce vessels which are suited to the services in which they will be employed.[3]

A good starting point is the stowage factor, the volume of hold space in cubic metres occupied by a tonne of cargo. This varies enormously from one commodity to another, as the examples in Table 14.2 show. Iron ore, the densest cargo, stows at around 0.4 m^3 per tonne, whilst wood chips stow at around 2.5 m^3 per tonne and thus take up six times as much space. In between is heavy grain which stows at around 1.3 m^3 per tonne. If a ship designed for grain is loaded with iron ore, much of the internal space will be empty. At the other end of the scale, light cargoes such as logs need a lot more space. So a bulk carrier designed with a cubic capacity of 1.3 m^3 per tonne could take a full cargo of coal, but not a full deadweight of wood pulp which stows at 1.7 m^3 per tonne.

If a ship is to be used exclusively to carry only iron ore, it can be designed as an ore carrier with cargo spaces stowing at, say, 0.5 m^3 per tonne, but if it is to be used for other commodities such as coal or grain an internal cubic capacity of about 1.3 m^3 per tonne might be preferred (see Table 14.9 for the average stowage of the bulk carrier fleet). The same problem arises with container-ships. Twenty-foot containers typically stow at around 1.6–3.0 m^3 per tonne, one of the least dense commodities listed in Table 14.2. To utilize the ship's deadweight, containers are generally stacked on deck but the design deadweight per container slot is a matter of balance because the weight of cargo in the containers may change. We saw in Chapter 13 that the average container payload per TEU in the transpacific trade varies between 7 tonnes eastbound and 12 tonnes westbound. So a compromise is needed on the ship's loaded deadweight.

Hold dimensions are also important. Ships carrying containers, packaged timber or any standard unit must be designed with square 'open' holds that match the external dimensions of the units they are carrying and provide vertical access. For example, 'pallet-friendly' reefer vessels are designed with decks tailored to accommodate the maximum payload of standard pallets.

Table 14.2 Stowage factors for various commodity trades

Cargo type	Stowage factor: Cu. ft/ton	Stowage factor: Cu. m./tonne	Density index[a]
Dry cargo			
Iron ore	14	0.40	31
Bauxite	28	0.80	62
Phosphate (rock)	30–34	1.00	77
Soya beans	44	1.20	92
Grain (heavy)	45	1.30	100
Coal	48	1.40	108
Barley	54	1.50	115
Wood pulp (bales)	60	1.70	131
Copra	73	2.10	162
Pre-slung timber	80	2.30	177
China clay (bagged)	80	2.30	177
Paper (rolls)	90	2.50	192
Wood chips	90	2.50	192
Logs	100	2.80	215
Containers, 20 ft	56–105	1.6–3.0	123–230
Containers, 40 ft	85–175	2.4–5.0	185–385
Cars (vehicle carrier)	150	4.2	323
Toys, footwear	300–400	8.5–11.3	230–869
Liquid cargo			0
Molasses	27.0	0.80	62
Heavy fuel oil	32.8	0.93	72
Heavy crude oil	33.7	0.95	73
Diesel oil	37.2	1.06	81
Light crude oil	37.6	1.07	82
Gas oil (light fuel oil)	38.6	1.10	84
Paraffin	40.3	1.14	88
Motor spirit (petrol)	43.2	1.23	95
Aviation spirit	45.1	1.28	98
Naphtha	46.4	1.32	101

[a]Density index based on grain (heavy) = 100. Big numbers take more hold space, whilst small numbers like iron ore take up little.

Source: Various

Where commodities with stowage factors that depart significantly from the average are shipped in large quantities, it may be economic to build specialist ships to carry them. Ore carriers, woodchip carriers and car carriers are three prominent examples, the first to deal with a high-density cargo and the latter two to deal efficiently with low density cargoes. Hoistable decks may be fitted to allow the head-room to be adjusted for different cargoes, for example to allow car carriers to transport larger units like trucks.

How should the cargo be handled?

Getting the cargo on and off the ship is one of the most important aspects of ship design, involving both the cargo characteristics and the extent to which the transport operation is part of a wider integrated transport network. There are many ways ship designs can be developed to improve cargo-handling efficiency, provided the dimensions of the units are known in advance. Some of the most important are as follows:

- *Cargo-handling gear*. Jib cranes, heavy lift derricks, or other cargo-handling gear such as gantry cranes may be fitted to speed up the loading and discharge of dry cargo ships. For tankers the there are three main issues to consider – the capacity of the pumps; corrosion resistance of pipe work; and segregation of tank cargo-handling systems.
- *Hatch design*. Bulk carriers for transporting unit loads such as containers or packaged lumber may be designed with hatch coamings that match the standard package size, thus facilitating the efficient stacking of packages in the hold and on deck. Wide (sometimes called 'open') hatches provide vertical access to all parts of the hold.
- *Cell guides*. In the case of containers the process of integrating the hold design into the cargo-handling operation goes a step further, and to speed up handling on container-ships, cell guides are fitted in the holds and occasionally on deck so that containers do not need to be secured individually below deck.
- *Cargo access ramps*. Ramps may be fitted to allow cargo to be loaded by fork-lift truck, or to be driven aboard on its own wheels. They may be located at the bow, the stern or into the side of the vessel, accessed through watertight doors in the hull.
- *Tank segregations*. For liquid cargoes the provision of 'self-contained' tanks capable of handling many different liquid parcels within a single ship increases flexibility. This generally involves the installation of separate pumping systems for each tank using submerged pumps and special coatings such as zinc silicate or stainless steel to allow difficult chemicals to be carried.

This is not an exhaustive list, but it illustrates the way in which ships may be adapted to the carriage of cargoes.

How big should the ship be?

With the issues over cargo handling and stowage out of the way, the next question facing the investor is the size of vessel to buy. There are numerous influences on the size of ship, but the principles of bulk shipping discussed in Chapter 11 suggest that the optimum size for a ship can be narrowed down to a trade-off between three factors: economies of scale; the parcel sizes in which cargo is available; and available port draught and cargo-handling facilities.

We discussed economies of scale in Chapter 7 and saw that substantial cost savings are achieved by using larger vessels, with the choice depending on the size of vessel used and the length of the voyage. The relative costs for large and small ships on short and long voyages are illustrated in Table 14.3. A 15,170 dwt vessel costs 2.7 times as much to run per ton of cargo as a 120,000 dwt ship on a 1000-mile round voyage, whilst on the 22,000 mile round voyage it costs 3.1 times as much.

Table 14.3 Economies of scale in bulk shipping (% cost per ton mile)

Round voyage (miles)	Ship size (dwt) 15,170	40,540	65,500	120,380
1,000	100	53	47	37
6,000	56	34	27	20
22,000	52	30	24	17

Source: Goss and Jones (1971, Table 3).

This suggests that economies of scale are only slightly influenced by the length of haul, and the fact that smaller ships are generally used on short routes must have another explanation.

In practice, big ships face two important restrictions. The first is the maximum size of delivery that the shipper is able or willing to accept at any one time. If stockpiles are only 10,000 or 15,000 tonnes, a delivery of 50,000 tonnes would be too large. Second, there is the constraint on ship size imposed by port draught since deep-draught vessels, have access to fewer ports than shallow-draught vessels, as shown in Table 14.4. Limits may also be placed on overall length or beam or both (either by ports or by canals). The measure of accessible ports is very crude, since some ports are more important than others in the bulk trades and depth varies substantially from berth to berth within ports, but the broad relationship is valid. At the lower end of the scale, a small bulk carrier of 16,000 dwt is likely to have a draught of 7–9 metres and is able to access about three-quarters of the world's ports. A final point is that ship designers can vary the draught–deadweight ratio within certain limits by changing other aspects of the design such as the beam.

Table 14.4 Relationship between ship draft and port access

Ship draught feet	Ship draught metres	Average size dwt	Standard deviation* dwt	% of world ports accessible
25–30	7.6–9.1	16,150	3,650	73
30–35	9.2–10.7	23,600	3,000	55
36–38	10.8–11.6	38,700	5,466	43
39–44	11.7–13.4	61,000	5,740	27
45–50	13.5–15.2	89,200	8,600	22
51–55	15.3–18.5	123,000	9,000	19

Source: Sample of bulk carriers from the Clarkson *Bulk Carrier Register* and *Ports of the World*
*Standard deviation is the spread of the average size

How fast should the ship go?

In terms of cargo delivery economics, size and speed are to some extent interchangeable because a ship's transport capacity can be increased by increasing either its size or its speed. However, the two methods have very different economic and physical consequences. From a design viewpoint the fast ship will generally be more expensive to build and achieving the higher speed may call for a longer hull with less efficient cargo stowage. But the fast ship needs less cargo capacity to achieve a given cargo delivery volume and it can access shallower draft ports and make more frequent deliveries, reducing inventory requirements. Speed also reduces the transit time and the inventory cost of cargo in transit, which can be very significant for high-value cargoes such as television sets which can be worth around $44,000 per tonne (Table 14.5). If a company's cost of capital is 10% per annum, a 10-tonne cargo of television sets worth $44,000 per ton would, on a two-month voyage, incur interest charges of $7,000. Cutting the journey to one month saves $3,500, so the shipper should be willing to pay for faster transport. In fact air freight often competes with sea transport for this sort of cargo and, although the tonnages are small, the competition is significant because it is premium cargo. But these benefits of speed come at a cost. To be efficient, fast ships need a long hull and use far more fuel, as can be seen from Table 14.7 which shows the speed and fuel consumption of container-ships. For example, it shows that the average container-ship of between 6,000 and 12,000 TEU has a speed of 25.2 knots burns 211.3 tonnes a day, more than twice as much as a 15 knot VLCC.

At the other end of the range, some bulk commodities such as iron ore and coal have very low values, for example iron ore at $35 per tonne and coal at around $47 per tonne (Table 14.5). These commodities are generally shipped in very large consignments (up to 300,000 tonnes) and, since they have a low inventory cost, the emphasis is on minimizing the unit transportation cost by using the most economical speed. For these cargoes the relevant cost is the cost of the ship, not the cargo. Ship designers will generally work out the optimum operating speed for the vessel, taking account of the anticipated level of capital, operating and bunker costs on the assumption that the freight is not time sensitive. However, an important qualification is that if the ship is to

Table 14.5 Value per ton of sea imports

Commodity	$ per tonne f.o.b.	Quantity traded, (million tonnes)	Value trade $m
Stone, sand, gravel	9	101	888
Iron ore	35	650	22,750
Coal	47	682	32,054
Grain	200	273	54,600
TV sets	43,076	—	—
World imports	1,341	6,893	9,244,700

Source: UNCTAD (2006) Table 41 and Annex 2 and various be traded on the spot market the investor may specify a design speed above this minimum so that he can complete more voyages during periods of high freight rates when he is making premium profits.

How flexible should the ship be?

Finally, there is the flexibility of the ship to consider – should the ship be designed to service several markets? Specialist tonnage is shut out from markets that could be serviced by more flexible vessels, or at least incurs a cost penalty, so naturally ship designers have devoted a great deal of attention to this question. This can raise issues over speed, cargo handling, cargo access, size, stowage and various less fundamental but expensive options such as tank coatings – for example, should a new Aframax tanker have tank coatings so that it can switch into the long-haul clean products trade?

A way of illustrating the degree of cargo unit flexibility of different ship designs is shown in Figure 14.2, which lists on the left-hand side the various cargo units we have discussed and on the right-hand side a range of recognized ship types. A line links each cargo unit to the various ships that are capable of transporting it, and for each ship type the lateral cargo mobility (LCM) coefficient records the number of different cargo units that the vessel can carry.

Four ships are sufficiently specialized to have an LCM rating of 1 – the container-ship, the vehicle carrier, the bulk carrier and the tanker. All these vessels are restricted to a single type of cargo unit. The combined carrier has an LCM rating of 2, reflecting its ability to switch between dry bulk and crude oil, while the open hatch bulk carrier can transport containers, pallets and pre-slung cargo in addition to dry bulk parcels. The ro-ro is even more flexible, with the ability to carry almost any cargo except bulk and barges, giving it an LCM rating of 6. However, the most flexible of all is the MPP cargo liner, which can carry everything except liquid bulk parcels and barges.

The trade-off between cost and operational performance in its main trade is central to the design of flexible ships. Often the flexible ship is more expensive

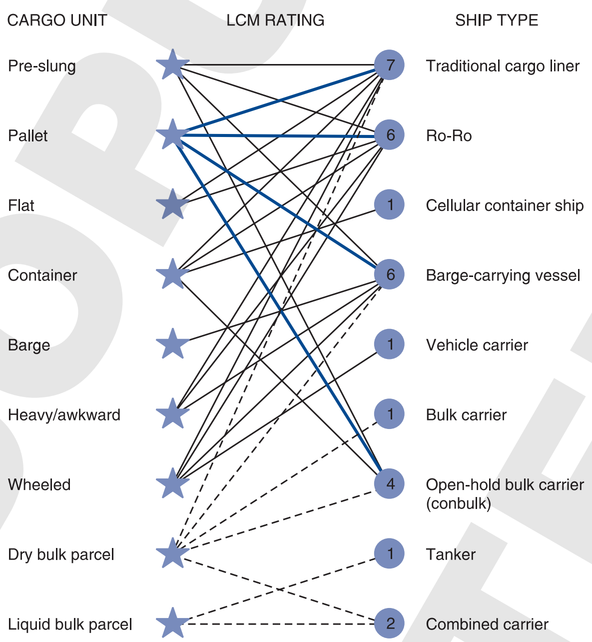


Figure 14.2
Analysis of flexibility
Source: Martin Stopford 2007
Note: Lateral cargo mobility (LCM) rating reflects the number of different types of cargo units that the vessel can carry, i.e. its flexibility. The higher the number, the greater the flexibility.

Table 14.6 Principal dimensions of flat roof steel containers

	Dimensions	
	20′ × 8′ × 8′6″	40′ × 8′ × 8′6″
Length (metres)	6.1	12.2
Width (metres)	2.44	2.44
Height (metres)	2.6	2.6
Cubic capacity (cubic metres)	32.9	67
Stacking capacity	9 high	9 high
Maximum weight (metric tonnes)	24	30.5

Source: UNCTAD (1985, p.141).

to build and does not perform as well as a single purpose vessel in any of the trades for which it is built. So the key is whether it can gain benefits such as reducing ballast voyages or carrying more cargo (see the example of open-hatch bulk carriers at the beginning of Chapter 12). In this context, design technology can be important in addressing operational issues. Although the case for flexible ships which reduce risk and increase earnings sounds great, in practice relatively few shipping investors follow this strategy. Today the merchant fleet is dominated by single-purpose ships such as tankers, bulk carriers and container-ships, all of which have an LCM ratio of 1. In contrast, the flexible ship types such as cargo liners, ro-ros, barge carriers and combined carriers have recently been noticeably sluggish or in retreat. This suggests that in the modern shipping industry the economic benefits of specialization outweigh the economic benefits from flexibility – a useful reminder that simplicity is a guiding principle of successful ship design. Sophisticated ships make interesting conference papers, but in the harsh commercial world simple vessels which do one job well seem to do better.

14.3 SHIPS FOR THE GENERAL CARGO TRADES

This is the trade segment where ships have changed most in the last fifty years. Indeed, it is rare in shipping to find such a radical change as the substitution of container-ships for the flexible cargo liners which started in the 1960s. Like the switch from sail to steel, the transition took many years to accomplish and a large number of vessels left over from the cargo liner era continued to be used and in some cases were still being replaced fifty years after the first container was shipped in 1956. By 2006 the container-ships had taken over all but the fringe liner services, though there were still a few services using ro-ros, MPP vessels and even a handful of barge-carrying vessels (BCVs), and ’tweendeck tramps.

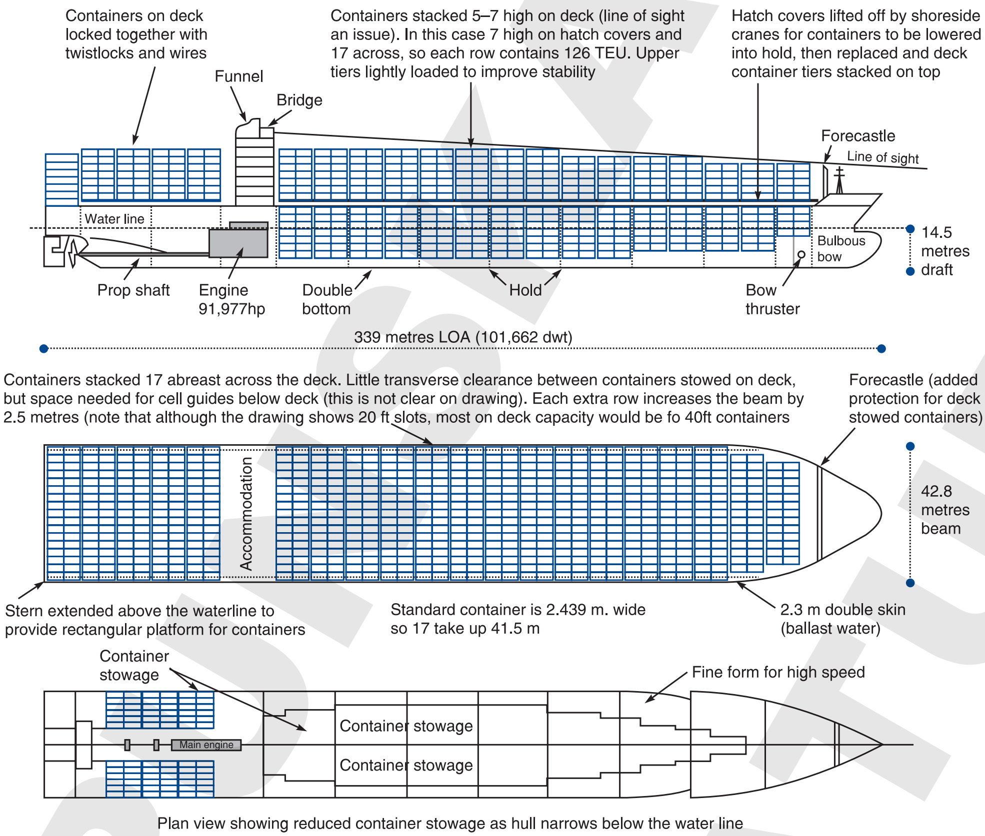
Container-ships

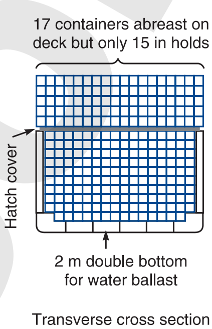
All the major liner trades now use container-ships. A container-ship is, in principle, an open-top box in which containers can be stacked. It has hatches the width of the holds, fitted with cell guides so that containers can be dropped into place and held securely during the voyage without lashing. The hatches are sealed with strengthened hatch covers which provide the base for stacking more containers above deck. Since these have no supporting structure they must be lashed in place with twistlocks and wires. Some companies have experimented with hatchless designs which avoid the labour-intensive procedure of clamping containers.

Details of a large 8200 TEU container ship are shown in Figure 14.3. Since the sole purpose of this ship is to carry containers, its design centres on container dimensions. ISO standards identify a range of containers, the most widely used sizes being the 20 ft and 40 ft containers with dimensions as shown in Table 14.6. Container-ships are generally designed around the 8 ft 6 in. high module, though this also allows a mix of 8 ft and 9 ft 6 in. containers to be stowed as well. The containers are arranged in bays, with 30 forward of the accommodation and 10 at the stern. Below deck the containers are lowered into cell guides and the number of tiers which can be accommodated in the hold varies with the curvature of the hull, as illustrated by the longitudinal cross section in Figure 14.3. On-deck containers are stacked on the hatch covers and held in place by twistlocks and wires and stacked in tiers the height of which depends on visibility. In this example the number of tiers varies between five and seven. The ISO also specifies a weight standard, which is a maximum of 24 tonnes for 20 ft containers and 30 tonnes for 40 ft containers. These are well above the average values likely to be found in practice, which may range between 10 and 15 tonnes depending on the trade and the type of cargo. Although this ship has a nominal capacity of 8189 containers, its homogeneous capacity at 14 tons per TEU is 6,130.

At first, container-ship designs were categorized into 'generations', reflecting the evolving technology, but as the fleet grew to more than 4,000 ships in 2007 it polarized into size categories shown by the fleet statistics in Table 14.7. Each sector has a different place in the market. Smaller container ships of less than 1,000 TEU, often referred to as 'Feeder' (0–499 TEU) and 'Feedermax' (500–999 TEU) vessels, are generally used on short-haul operations. They distribute the containers brought to regional load centres or 'hub' ports such as Rotterdam by deep-sea services and carry coastal traffic. There is a sizeable fleet of Handy vessels of 1,000–3,000 TEU which are small enough to be used intraregionally, but large enough to be used in the North–South trades where port restrictions or cargo volume do not permit the use of a larger vessel. Bigger ships over 3,000 TEU are used on long-haul trades where they spend up to 80% of their time at sea. There are three groups of these vessels, referred to as Panamax (3,000–4,000 TEU) and post-Panamax (over 4,000 TEU), with an evolving group of very large box carriers (VLBCs) over 6,000 TEU. Since the different fleet segments have different functions they also have different design characteristics, especially speed and cargo-handling facilities.

Speed is a central feature of container-ship design; with the larger vessels having higher speeds, as can be seen in Table 14.7. In 2006 the average Feeder vessel had a speed of 14 knots, compared with an average speed of 24.5 knots for the average post-Panamax vessel. With each step up in size the speed increases, though the pace of increase slows sharply over 3,000 TEU. The economic explanation of this trend is that





8,200 TEU Container-ship

HULL	CARGO	MACHINERY
Deadweight (design): 84,200	Maximum TEU capacity: 8,189	Engine: MAN-B&W
Deadweight (scantling): 101,662	on deck 4,148	Power output (hp): 91,977
Gross tonnage: 88,600	in holds	4,041 at 97 rpm (67.6 MW)
dimensions	TEU capacity @14t per TEU: 6,130	Six bladed propeller
Overall length (m): 339		Maximum speed (Kn): 25.4
Overall beam (m): 42.8	Container tiers/rows:	Speed, service 90% MCR*
	On deck: 7/17	15% sea margin 24.4 knots
Draft (m): scantling 14.5	In holds: 8/15	Consumption: 271 tons/day
Draft (m): design 13.0	TEU bays on deck: 19	Bunker capacity:
Width of double side: 2.23 m	TEU bays below deck: 18	heavy oil 10,900 m^3
Height of double bottom: 2.00 m	Reefer containers: 700 electric	diesel oil 700 m^3
Percent high tensile steel 60%	sockets to supply 40' boxes	Diesel alternators 5
	complement	Alternator output:
	Officers 16	3×2200 kW and 2×2800 kW
Tin free SPC paint, 5 year life	Ratings 18	Exhaust gas scrubbing plant
	Suez crew 6	Bow thruster 1×2500 kW

*MCR is the maximum continuous rating i.e. maximum power

Figure 14.3

Example of typical 8,200 TEU container-ship design

Source: Drawing by Martin Stopford, based on container-ships built by Hyundai Heavy Industries

Table 14.7 The container-ship fleet, by size and hull characteristics

		Container-ship fleet size			Hull characteristics					
	Ship size TEU	No	Av. TEU	Tot TEU (000s)	Capacity dwt/TEU	Beam metres	Draft metres	Speed knots	Cons. t/day	% Geared
Feeder	0–499	443	310	137	17.2	17.1	6.1	14.0	15.7	29%
Feedermax	500–999	695	722	502	14.1	21.1	7.7	16.8	27.5	48%
Handy	1000–1999	1012	1412	1429	14.9	26.3	9.7	19.0	49.2	53%
Sub-Panamax	2000–2999	596	2504	1492	14.2	31.0	11.5	21.2	79.3	43%
Panamax	3000–3999	297	3411	1013	13.8	32.3	12.0	22.5	104.5	9%
Post-Panamax	4000–5999	533	4817	2567	12.9	35.4	13.3	24.5	159.5	0%
VLBC	6000–12000	215	7419	1595	12.6	41.9	14.2	25.2	211.3	0%
Total	Grand total	3791	2304	8736	13.6	27.6	10.0	19.7	64.5	34%

Source: *Container-ship Register* 2006, Clarkson Research Services Ltd, London

the bigger ships are generally used on long-haul routes where speed is an important aspect of the service. High speed brings a cost penalty in terms of fuel consumption and restricted hull design, since high speeds require a fine hull form. For short-haul trades where there are many port calls, speed is less important than economy and cargo payload. Conversely, on long hauls speed is highly productive, reducing journey times and the number of ships required to run a service. Whatever the economic justification, and it is complex, the relationship between speed and size in container-ships is clear.

Cargo-handling gear also varies with size, following a similar pattern to the bulk carrier fleet. Many of the smaller vessels carry cargo gear and the larger container-ships rely exclusively on shore-based cargo-handling facilities. In 2006, 29% of the Feeder vessels, 48% of the Feedermaxes, 53% of the Handy container-ships, and 43% of sub-Panamax container-ships had cargo gear, but only 9% of post-Panamax container-ships.

One of the most important ways of increasing container-ship versatility is to carry *refrigerated containers*, enabling the container companies to compete with reefer operators for the trade in meat, dairy products and fruit. This can be achieved by insulating the containers which have their own refrigeration units that plug into a power plug on the ship. If a substantial regular volume of reefer cargo is available (e.g., on the Australia to UK route), a central refrigeration plant may be built into the ship. This blows cold air through ducts into the insulated containers. At the loading and discharging ports the insulated containers must be stored in special refrigerated reception facilities or portable refrigeration plants are used. Containers with their own refrigeration plant can be plugged into electrical socket adjacent to each container slot. In addition to fast cargo handling, refrigerated containers offer shippers precise temperature control through the journey and a better-quality product, which in the case of fruit and vegetables may result in a higher selling price.[4]

Finally, there has also been much research into containers for transporting small bulk cargoes. These include the use of ventilated containers for agricultural commodities such as coffee and cocoa beans, tank containers for bulk liquids, and containers with special loading and discharging facilities for the fast automated handling of minor bulk commodities. As we saw in Chapter 13, bulk cargoes such as wool, rubber, latex, cotton and some forest products can now be containerized.

Other general cargo ships

Although container-ships dominate the transport of general cargo, in 2006 there was a fleet of 4717 other general cargo ship types operating in this market segment. The statistics are summarized in Table 14.8 which covers six ship types: ro-ro ships; MPP vessels; heavy lift; traditional liner types; tramps; and barge carriers. These fleet categories are not precise, since the dividing line between, for example, a liner type and a tramp is blurred. From the analyst's viewpoint this is a difficult segment because it has two different components. The first is a group of obsolete traditional liner vessels which, year by year, are being squeezed out by the more efficient container-ships. Liner types and tramps are obvious examples of vessels which fall into this category, and for them there is no question of replacement. But there is a second group of ships, possibly overlapping with the first group, which carry the cargo that container-ships cannot carry. Ro-ro vessels, MPPs and heavy lift ships all fall into this category. Unfortunately, in statistical terms we cannot precisely divide the fleet, but the consequences of this division are important for ship demand. Obsolete vessels will be replaced by container-ships, but the second group focusing on non-containerizable cargo is likely to continue to grow because there will always be a large number of cargos which do not conveniently fit in a standard container.

The key issue for vessels operating in these trades is the flexibility to carry containers, but the ability to also transport uncontainerizable general cargo which, for the reasons discussed in Section 12.6, cannot be transported in container-ships. Common examples are project cargos, forest products, palletized cargo, and wheeled vehicles. In the following paragraphs we will discuss seven different categories of ships which fall into this class.

RO-RO SHIPS

Cargo ro-ros offer a more flexible alternative to containerization for transporting a mix of containerized and wheeled cargo with cargoes ranging from mini-bulks in intermediate

Table 14.8 The general cargo fleet, by size and hull characteristics

Type	TEU '000s	Number	Av. TEU	Av. dwt	Age (yrs)	Av. speed (units)
Ro-ro	1,440	1,109	1,604	12,132	20	17.1
MPP	1,057	2,533	417	9,142	16	14.2
Heavy lift	15	40	364	18,031	21	13.9
Liner type	89	401	222	13,822	29	16.1
Tramp	93	624	149	8,970	16	12.9
Barge carrier	10	10	1,006	25,642	24	15.8
Grand total	2,703	4,717	627	14,623	21	15.0

Source: *Containership Register* 2006, Clarkson Research Services Ltd bulk containers and pallets through to heavy lift units of 90 tonnes. These are interesting ships and several designs were developed, but in concept the ro-ro is a cargo liner with 'through decks' and roll-on access by means of ramps, rather than via hatches in the weather deck. Key design features are access ramps, open decks allowing fast manoeuvring of fork-lift trucks, tractor/trailers and wheeled vehicles, good access between decks, and deck and ramp loadings for heavy cargoes. They are particularly suitable for carrying any cargo that can easily be handled by a fork-lift truck (pallets, bales, containers, packaged timber, etc.) and also for wheeled cargo (cars, loaded trucks or trailers, tractors, etc.). A major advantage of the ro-ro vessel is its ability to provide fast port turnaround without special cargo-handling facilities.

Apart from some Scandinavian devotees, ro-ros never found a market in the deep-sea cargo trades (though they were more successful in the short-sea passenger-cargo ro-ro market) and in 2006 the fleet of 1109 vessels had an average age of 20 years, suggesting that the fleet is not being replaced (Table 14.8). There were only two small vessels on order. Although ro-ros have never been adopted on the scale of cellular container-ships, the existing fleet continues to be used in some trades where the cargo mix and port facilities favour this type of operation, for example the Atlantic Container Line ships discussed in Chapter 12. The explanation for this poor performance seems to be that although ro-ros have highly flexible cargo capacity, with an LCM coefficient of 6, and can handle cargo efficiently even in ports with very basic facilities, this flexibility has a price that makes it unacceptable to investors. The ships have much less efficient stowage than container-ships and, since the cargo is more difficult and labour-intensive to secure, the loading times are generally slower. In addition, ro-ros are very management-intensive, requiring careful stowage planning.[5] However, their greatest disadvantage is that they lack the simple integration with other transport systems which is the chief asset of the container-ship fleet. As a result the ro-ro fleet is very much smaller than the container fleet, and even on routes such as the West Africa trade where suitable conditions exist, ro-ros account for only about 10% of the tonnage employed.[6]

MULTI-PURPOSE VESSELS

Where there is a continuing demand for flexible liner tonnage, MPP or lo-lo (lift on, lift off) vessels are used. Ships of this type are typically between 8,000 and 22,000 dwt with three to five holds, each containing a 'tween deck. The main difference from earlier traditional liners is that they are designed to carry a full load of containers as well as general cargo and heavy lift. This is achieved by designing the lower hold and the 'tween deck with dimensions compatible with containers and container cranes capable of 35–40 tonne lift. Table 14.8 shows that in 2006 there was a fleet of 2,533 MPP ships with an average size of 9,142 dwt and an average age of 16 years. The fleet grew at 2.6% per annum between 1996 and 2006 (Table 12.12), demonstrating that there is a positive demand which has become more apparent as the container business has matured.

In economic terms, MPP vessels are a compromise for use in trades that are partly containerized, especially for heavy and awkward cargoes which cannot be containerized, and their ability to pick up bulk cargoes helps to increase deadweight utilization.

The downside is reduced efficiency handling containers, since they do not have cell guides and they are expensive to build. However, even basic MPPs often have a lateral cargo mobility rating of 5, with the ability to carry pre-slung cargo, palletized cargo, flats, containers, heavy and awkward cargo, and wheeled vehicles, but designs vary a great deal. Since there are many permutations it is useful to review some examples which illustrate the principal features of this ship type and how they can be varied.

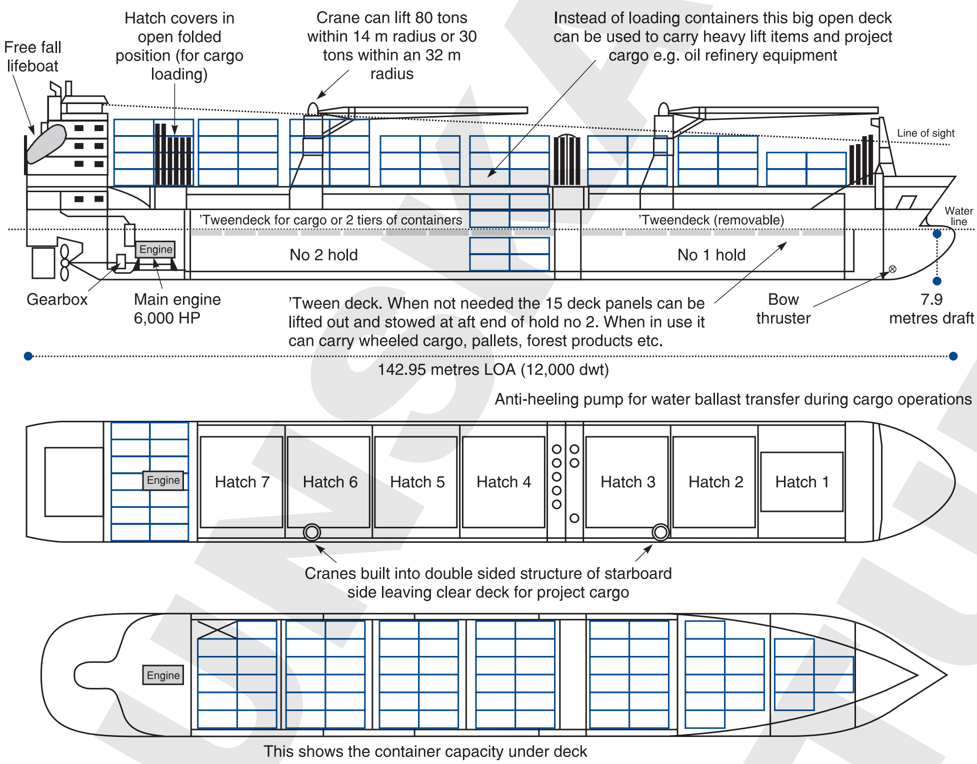
An example at the top end of the size range is a 23,700 dwt MPP vessel aimed mainly at the container and packaged bulk cargo markets. It has a container capacity of 1050 TEU, five holds with mechanically operated 'tween decks and a relatively fast speed of 18.5 knots on 50 tons a day. The cranes are of 35 tonne and 26 tonne capacity, so this is quite a high specification. In addition to containers, the vessel can carry wood products, steel products, construction materials, general cargo and project cargo including yachts and heavy machinery. Fragile or non-unitized cargoes such as packaged consumer items, perishable produce and chemicals can also be accommodated and the ship has capacity for 150 refrigerated containers. Containers can be stacked up to four high in the holds and three high on the hatch covers, and the holds and open hatches are designed to accommodate containers of 20 ft or 40 ft in length.

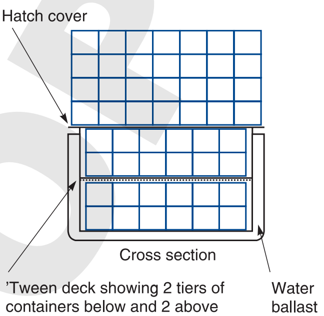
Figure 14.4 shows outline drawings for a smaller MPP aimed more at the heavy lift and project cargo markets. It is 12,000 dwt and can carry 684 TEU. Two cranes capable of lifting up to 80 tonnes, a big open deck and removable 'tween decks allow it to service a whole range of project and heavy lift cargoes. This particular vessel has been designed to a gross tonnage of 8,999, to comply with the Dutch manning requirements, and it has a crew of 13.

Basically this is a single-deck open-hatch design, with two very long holds, hydraulic folding hatch covers, and a removable 'tween deck. The 'tween deck is made up of 15 panels which can be lifted out and stowed at the aft end of no. 2 hold when not in use. The design is heavily focused towards the transport of containers, carrying 372 TEU on deck and 312 TEU in the holds. Four tiers of containers can be stacked in the hold, two below the 'tween deck and two above, allowing mixed container and unit cargoes to be carried in the holds when the 'tween deck is in place. Another two to four tiers of containers can be stacked on the deck, with the height of the foreward tiers reduced for better visibility from the bridge. There are also 80 reefer plugs. Six rows of containers can be accommodated in the hold and seven rows on deck.

For project and heavy lift cargoes, the ship has two electric hydraulic deck cranes, each capable of lifting 30–80 tonnes (at 80 tonnes the lift is restricted to a 14 metre radius, whilst at 30 tonnes the radius extends to 32 metres). In order to leave the stowage space on deck open for project cargos, the cranes are built into the side shell (i.e. the double side – see Figure 14.4). This means that the ship has an open deck/hatch area over 100 metres long on which to carry project cargoes. An anti-heeling pump for use during cargo operations is located in the space between holds nos 1 and 2 along with air drying equipment.

The advantage of this arrangement is that the vessel can carry a mix of containers and general cargo in the hold, whilst having the option to carry heavy project cargos on deck, or a full load of containers if no such cargoes are available. Taken together, this





12,000 Deadweight MPP Ship

CAPACITY	HULL	PROPULSION & EQUIPMENT
Maximum TEU capacity: 684	Ice strengthened to class 1A	Engine: Caterpillar MaK
on deck 372	*dimensions*	Power output (hp): 6,000 4.4 MW
in holds 312	Overall length (m): 142.9	Gearbox: 1 output 121 rev/min
Reefer plugs: 80	Overall beam (m): 18.9	Propeller diameter: 5000 mm
	Depth, to main deck 10.95	Maximum speed (knots): 16
On deck: 4 tiers and 7 rows	Draft (m): scantling 8.08	Consumption: 25 tons/day
Below deck: 4 tiers and 6 rows	Draft (m): design 7.93	Bunker capacity:
TEU bays on deck: 8	Width of double side: 2.23 m	heavy oil 765 m^3
TEU bays below deck: 7	Height of double bottom: 2.00 m	diesel oil 105 m^3
Cargo capacity: 17,273 m^3	No 1 Hold (m): 40.9×15.8×10.5	Water ballast 4790 m^3
	No 2 Hold (m): 55.9×15.9×10.5	Alternator main engine driven: 1
Deadweight (scantling): 12,000	'Tween deck: 15 removable panels*	Alternators diesel driven: 3
Deadweight (design): 11,650	*cargo gear*	3×430 kW/1500 rpm
Gross tonnage: 8,999	Cargo cranes**: 2 Liebherr	Exhaust gas scrubbing plant
compliment	electric-hydraulic; cylinder luffing	Bow thruster 1×730 kW
Officers 8	Lift (tonnes) Radius	
Crew 5	80 14 m	hatch covers: hydraulic, folding
Suez crew 4	Max lift 40 28 m	Mooring winches: 2
	30 32 m	Anti-heeling pump: 1

*the 'tween deck panels stow at the aft end of hold no 2 when not in use. Can be used as grain divisions.
**crane structure built into double side, leaving deck and hatch cover space clear for project cargo.

Figure 14.4
Multi-purpose heavy lift ship, 12,000 dwt
Source: Drawing by Martin Stopford, based on Damen Shipyard Combi-Freighter design

offers a high degree of flexibility and good operating efficiency, but it is a very different design philosophy from the dedicated container-ship reviewed in Figure 14.3. Ships of this sort fill an important role in the shipping market and because they are generally expensive to build and require careful marketing to achieve the best mix of cargo, the business philosophy is very different from the deep-sea container and commodity trades.

HEAVY LIFT VESSELS

Heavy lift ships focus exclusively on large awkward cargo items. They range from items of industrial plant to offshore equipment, project cargo, and container cranes. As far as the ship design is concerned, there are basically three ways of dealing with heavy unit loads. The first is to lift it on and off the ship, generally using cranes with a high lifting capacity. MPP vessels with heavy lift capacity and ro-ros can carry unit loads of up to 100 tonnes, but there is a demand for small vessels capable of carrying much larger loads (e.g. up to 500 tonnes) or on routes where liner companies do not offer heavy lift capabilities. The second is to roll the cargo on or off the ship using a strengthened ramp, of the type fitted to some ro-ros. Modern vehicle carriers often have strengthened ramps and hoistable decks so that they can load heavy wheeled vehicles and industrial plant. The third is the float-on, float-off method in which the ship itself is submerged, allowing the heavy unit such as dredging plant to be floated on to the vessel for loading, and then removed in the same way. The market for these vessels is discussed in Section 12.6.

CARGO LINER TYPES

Finally, we come to the general cargo fleet, which in 2006 was 401 ships with an average size of 13,800 dwt and an average age of 29 years (Table 14.8). These are history, the last remnants of the multi-deck ships used in the liner services, for example Ocean's *Priam* class cargo liner built in the 1960s. They had 'tween decks for mixed general cargo, tanks for carrying liquid parcels, refrigerated capacity and could also carry small bulk parcels (e.g. minor amounts of ore, copra, steel) in the lower hold. Often they had cargo-handling gear with heavy lift ability, but little attention was paid to container capacity. Some are still in service but, needless to say, they are not being replaced.

'TWEENDECKER TRAMPS

The 'tweendecker tramps are simpler versions of the cargo liner types. In 2006 there were over 624 ships of 5.5 m.dwt in service. Typically these vessels range in size from 10,000 to 22,000 dwt and are essentially small bulk carriers with a 'tween deck so that they can carry a mix of general cargo and bulk cargoes such as grain. Since the mid-1950s, the rapid growth of parcel size in the bulk trades and containerization of general cargo has resulted in the 'tweendecker being replaced by MPP vessels, but the type is still used in some trades. In 2006 the average fleet age was 16 years and the average ship was 8970 dwt with a speed of 12.8 knots trading largely in the Third World.

BARGE-CARRYING VESSELS

The 1960s was a decade of great experimentation in the liner trades. The barge carrier was an extreme design developed to extend the benefits of unitization to the mini-bulk cargoes previously carried as bottom cargo. The concept involved grouping 'floating holds' (i.e. barges), generally of 400–1,000 tonnes, within a single ship. These barges could be filled with general cargo or small bulk parcels, making barge systems at least as flexible as the traditional cargo liner in terms of range of cargoes carried. The main design feature is the method employed for getting the heavy barges into the barge carrier – the LASH system used a shipboard crane, and the BACAT system floated the barges on to the ship. The barge carrier system has not been widely adopted. In 2006 there were only ten barge carriers, but not all were operating.

REFRIGERATED VESSELS

Refrigerated vessels (reefers) were developed in the late nineteenth century to carry meat from New Zealand and Australia to the UK (see Chapter 12 for a discussion of the trade). Reefer cargo is frozen or chilled, in which case the temperature is maintained just above freezing. To achieve this reefer vessels have insulated cargo holds with cargo handled horizontally through side ports and vertically through hatches.

Modern vessels have their cargo spaces designed for palletized cargo and there may also be reefer container capacity on deck or in the holds plus conventional container capacity. For example a 14,800 dwt vessel delivered in 2006 had 460,000 cubic feet of refrigerated capacity, 880 TEU, and 144 reefer plugs. The speed was 20.5 knots on 67 tons per day. For fruit and vegetables the cargo continues to ripen during transit, so the refrigeration system must maintain a precisely controlled temperature in all parts of the cargo spaces. Since fruit cargoes such as bananas are frequently loaded in developing countries with poor port facilities, there is often a need to make the ships self-sufficient in terms of cargo handling. Cars are often carried as a backhaul.

Although reefers dominated the refrigerated cargo trade, the fleet of 1,800 vessels is now very old, with an average age of 23.9 years (see Table 2.5). Refrigerated foods are increasingly transported in reefer containers.

14.4 SHIPS FOR THE DRY BULK TRADES

In the bulk cargo market, the focus is on low-cost transport. The bulk carrier fleet (Table 14.9) consists of over 6,000 vessels of 369 m.dwt. The fleet falls into four main parts generally referred to as Handy bulk carriers (10,000–39,999 dwt), Handymax bulk carriers (40,000–59,999 dwt), Panamax (60,000–99,999 dwt)[7] and Capesize (over 100,000 dwt). These ships carry a wide spectrum of bulk cargoes ranging from grain, phosphate rock, iron ore and coal, to parcels of chemicals, with a premium on economy and flexibility.

The bulk carrier

Nowadays the major bulk cargoes and the great majority of minor bulk cargoes are transported in bulk carriers. These are all single-deck ships with a double bottom, vertical cargo access through hatches in the weather deck and speeds generally in the range of 13–16 knots, though the average for most sizes is about 14.5 knots. Since the mid-1960s

Table 14.9 Bulk carrier fleet, February 2007, by size and hull characteristics

	Bulk carrier fleet size			Hull characteristics						
Size	No	Av.dwt 000s	Total dwt	Length m.	Beam m.	Draft m.	Speed knots	Cons. t/day	Cubic m^3/tonne	% geared
Handy										
10–19,999	611	15,679	9.6	136	22	8.7	14.1	22.5	1.22	73%
20–24,999	487	23,025	11.2	154	24	9.7	14.3	26.1	1.27	89%
25–29,999	820	27,627	22.7	166	25	9.9	14.3	28.6	1.28	93%
30–39,999	917	35,270	32.3	178	27	10.7	14.4	31.3	1.25	87%
Handymax										
40–49,999	969	44,761	43.4	182	31	11.4	14.4	30.4	1.31	94%
50–59,999	498	53,026	26.4	186	32	12.1	14.5	34.4	1.28	80%
Panamax										
60–79,999	1,292	71,350	92.2	218	32	13.4	14.4	36.7	1.18	7%
80–99,999	121	87,542	10.6	230	37	13.7	14.3	42.0	1.14	2%
Capesize										
100–149,999	173	137,714	23.8	257	43	16.6	14.2	49.8	1.10	2%
150–199,999	468	170,227	79.7	276	45	17.6	14.5	53.9	1.09	0%
199,999+	74	229,096	17.0	303	52	18.9	14.0	60.3	0.87	1%
Grand total	6,430	57,355	368.8	191	30	11.9	14.4	33.4	1.18	60%

Source: *Bulk Carrier Register* 2006, Clarkson Research Studies, London

there has been a steady upward trend in the size of ship used in most bulk trades. For example, in 1969 only about 5% of the iron ore was shipped in vessels over 80,000 dwt, but by the early 1990s over 80% of the trade was shipped in vessels of this size, mainly 150,000–180,000 dwt.

In fact the bulk carrier market has evolved into several different size bands, each focusing on a different sector of the trade, and as a result the ships in the bulk carrier fleet are spread fairly evenly across the size range, with the greatest concentration by numbers in the smaller sizes as shown in Table 14.9. At the smaller end of the range, Handy bulk carriers of 10,000–40,000 dwt fill the role of flexible workhorses in trades where parcel size and draft restrictions demand small ships. Typically they carry minor bulks and smaller parcels of major bulks such as grain, coal and bauxite and in busy maritime areas such as Asia can often complete two loaded voyages for every ballast voyage. This is a great improvement over the larger bulk carriers which often alternate loaded and ballast voyages.

As ports have improved over the last 20 years, a new generation of larger 40,000–60,000 dwt Handy bulkers has emerged, generally referred to as Handymax bulk carriers. Like the Handy bulkers, these vessels are generally geared. In the centre of the market are the Panamax bulk carriers of 60,000–100,000 dwt, which service the trades in coal, grain, bauxite and the larger minor bulk parcels. These medium-sized ships are named Panamaxes because they can transit the Panama Canal, but vessels at the larger end of the range are too big to do so, at least until the Canal is extended. The upper end is served by bulk carriers of 100,000–300,000 dwt, which are heavily dependent on the iron ore and coal trades. There is a good deal of interchange between these size groups and in the last resort the choice is a trade-off between unit cost and cargo flexibility: the small vessel is flexible but expensive to run, while the large vessels become progressively cheaper and more inflexible.

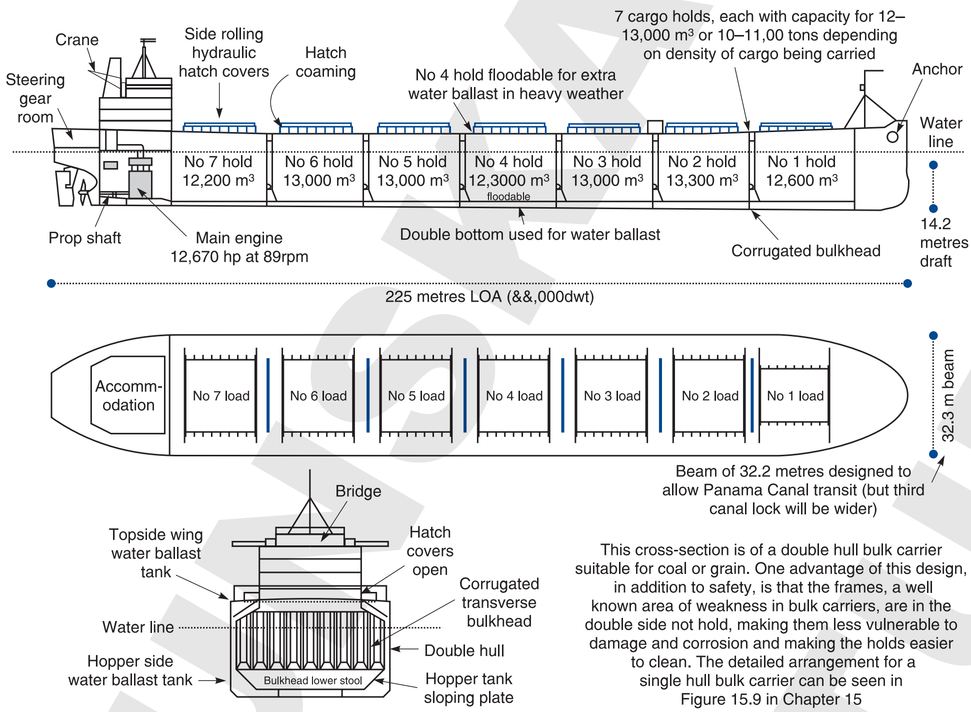
Bulk carriers are generally designed for cheapness and simplicity. Key design features are cubic capacity, access to the holds, and cargo-handling gear. Hold design is important because cargoes such as grain can easily shift and, if unchecked, can capsize the ship. To prevent this, bulk carriers generally have self-trimming holds in which the topside wing tanks are sloped in such a way that granular cargoes can be loaded by gravity without having to trim the cargo out into the wings of the hold.

On conventional bulk carriers, hatch openings are generally 45–60% of the beam (width) and around 65–75% of the hold's length. This arrangement has the disadvantage that hatch openings are too narrow to allow vertical access to all parts of the cargo hold, with the result that it is difficult to handle large cargo units such as rolls of paper, steel products, pre-slung timber, cars loaded in pallets or containers in a single operation. However, because the deck makes an important contribution to the structural strength of the ship, wider hatches can only be accommodated by adding structural steel to reinforce the vessel, considerably increasing costs. The hatch widths described above represent a trade-off between cargo-handling speed and building cost that has been found to work well in practice.

Most bulk carriers are fitted with steel hatch covers, of which there are several designs available. The self-supporting type is the most popular. Each hatch cover has four to six sections extending across the hatchway, with rollers operating on a runway. The covers are opened by rolling them to the end of the hatch where they tip automatically into a vertical position so that they are not in the way during cargo handling. Another consideration is whether or not to fit cargo-handling gear. Cargo-handling gear is normally fitted to smaller bulk carriers, since they are more likely to operate into ports with inadequate shore-based facilities. Table 14.9 shows that few bulk carriers over 50,000 dwt have cargo-handling gear, compared with 80–90% of smaller vessels. This is because the transport operations for bigger ships generally involve specialist terminals with purpose-built cargo-handling facilities so that they can turn around quickly.

The cargo gear is generally cranes, since derricks are now largely obsolete. A common arrangement for Handymax bulk carriers is to fit four 30- or 35-tonne cranes serving holds 1–4 and 5. Occasionally gantry cranes on rails are fitted, especially for the forest products trade, whilst continuous self-discharging bulk carriers take an even more radical approach to cargo handling. They use a shipboard conveyor system fed by gravity from the bottom of the holds. This allows them to unload cargo at rates of up to 6,000 tonnes per hour, though the high cost and the weight of the cargo-handling equipment mean that they are most economic in short-haul trades involving many cargo-handling operations.

The bulk carrier illustrated in Figure 14.5 is a 77,000 dwt Panamax vessel, one of the new generation with a double hull. It has seven holds, each with a grain capacity of around 13,000 cubic metres, or around 11,000 tonnes of cargo, depending on density.



77,000 Deadweight Panamax Bulk Carrier

HULL	CARGO	MACHINERY & EQUIPMENT
Deadweight (summer draft): 77,053	Strengthened for heavy cargoes	Engine: MAN B&W 5S60MC-C two-stroke
Deadweight (winter draft): 75,073	Bale capacity: 89,121 m³	Power max (hp): 12,670@89 rpm (9.32 MW)
Gross tonnage: 40,424	*hatches*	Power continuous: 10,135@83 rpm (7.45 MW)
Net tonnage (international): 25,482	Hatch dimensions: 1 18.8×14.1	Maximum speed (knots): 14.5 (15% SM)
	6 17.9×19.3	Fuel consumption: 35 tons/day
dimensions (all in metres)	hatch covers: side rolling, hydraulic	
Length, overall (m): 225.0	*Cargo capacity of holds*	*auxiliary engines*
Length between perpendiculars: 220.0	Grain 000 m³ 000 tonnes	Generators: 2 AC generators 475 KVA
Overall beam (m): 32.3	No 1 Hold: 12.6 10.5 at 1.2m³/t	Generator engines: 2×570 hp diesels
Summer draft (m): scantling 14.19	No 2 Hold: 13.3 11.1 typical of	Aux boiler: 1 cylindrical composite boiler
Winter draft (m): scantling 13.90	No 3 Hold: 13.0 10.9 coal	Emergency generator: 120 KVA
	No 4 Hold: 12.3 10.3	Ballast pumps: 2 centrifugal type 800 m³/h
tank capacities	No 5 Hold: 13.0 10.9	Fire pumps: 2 centrifugal type
heavy oil 2,193 m³	No 6 Hold: 13.0 10.9	*Crew*
diesel oil 145 m³	No 7 Hold: 12.2 10.2	Officers: 9
lubricating oil 114 m³	Total 89.5 74.6	Petty officer: 3
water ballast 37,164 m³	Holds, Nos 2, 4 and 6 may be empty	Ratings, pilot, 2 spare 14
	with dense iron ore in holds 1, 3, 5, and 7	Total 24 + 2 spare

Figure 14.5
Panamax bulk carrier (77,000 dwt), built 2006
Source: Drawing by Martin Stopford based on vessel built by Oshima Shipbuilding Co., Japan

The holds are separated by corrugated bulk heads and the hatch covers are very wide, about 60% of the beam of the vessel, giving improved vertical access to the holds. Since this is a Panamax vessel the beam is 32.3 metres, the maximum which can transit the Panama Canal (before it is widened). The vessel has a slow-speed two-stroke engine generating 12,670 hp at 89 rpm and the speed is a comparatively modest 14.5 knots on a consumption of 35 tonnes per day, which is normal for a bulk carrier. There are two AC generators driven by diesel engines, an auxiliary boiler and an emergency generator. In addition, the ship has two ballast pumps handling 800 cubic metres an hour and ballast water is carried in the topside tanks, the double bottom and hopper side tanks and a floodable hold for use in heavy weather.

The open hatch bulk carrier (conbulker)

There was a fleet of 480 open hatch bulk carriers in 2006 ranging in size from 10,000 to 69,000 dwt. They are designed to offer direct access to the hold through hatches which extend the full width of the vessel, allowing large cargo units to be lowered into place. Where possible the holds/hatches are designed around standard cargo unit sizes, including containers, with special attention paid to shipboard cargo-handling gear, and sometimes a gantry crane is fitted. All this is expensive because when the hatches are widened extra steel is needed to provide strength and the cargo-handling gear adds to the cost. As a result, a high-specification open-hatch bulk carrier can cost up to 50% more than a conventional vessel of the same size. Typically the 'open' hatches extend the full width of the vessel. This is particularly useful for forest products, which stow at anything from 2.3 cubic metres per tonne for pre-slung timber to 2.8 cubic metres per tonne for logs, and the heavy units are difficult to handle through the narrow hatches of a conventional bulk carrier or 'tweendecker. Open-hatch bulk carriers can also be used to carry containers on the outward leg, and dry bulk on the return leg which is particularly useful for repositioning empty containers between regions.

Woodchip carriers

Woodchip carriers have a high internal cubic capacity to accommodate the low-density woodchips. There were 129 ships in the bulk fleet in 2006 ranging in size from 12,000 to 74,000 dwt and typically cargo stows at around 2.5 m^3 per deadweight compared with 1.3 m^3 per deadweight for a general-purpose bulk carrier. Some are fitted with gantry cranes, though shore-based pneumatic handling equipment is often used.

Ore carriers

Ore carriers originally found a market because of the high density of iron ore, which stows at approximately 0.5 m^3 per tonne, compared with a normal bulk carrier's capacity of 1.3–1.4 m^3 per ton. They are built with holds designed for this high-density cargo, though general-purpose bulk carriers with strengthened holds or combined carriers are preferred owing to their more flexible trading opportunities. A few very large ore carriers have been built and some converted from single-hull tankers. In 2006 there were about 51 ore carriers in the fleet.

Pure car carriers

Another trade for which specialized bulk ships have been built is wheeled cargo. This is a rapidly growing segment, with 594 vessels in 2006. Initially cars were shipped in cargo liners but, as the volume of seaborne trade increased in the 1960s, bulk shipment became economically viable. The first development was to fit bulk carriers with car decks that could fold up to allow other bulk cargoes to be carried – a classic combined voyage was cars from Emden to San Francisco, returning with grain to Rotterdam. However, the low carrying capacity of car bulkers (one car per 13 dwt), combined with the additional weight of the decks, the slow loading and a high risk of damage in transit, made them a poor compromise.

As the car trade grew in size in the 1970s, vehicle carriers were purpose-built to carry new cars and small commercial vehicles such as vans and pick-ups. They have multiple decks (anything from 4 to 13 depending on size) with a high cubic capacity to deadweight ratio (e.g. one car per 3 dwt), high speed (around 20 knots for the bigger ones), ro-ro loading/discharging facilities, and internal decks and ramps carefully designed to speed cargo handling and minimize damage.

The fleet varies in size and operation from ships of 499 grt with four decks each, carrying 500 cars in the European short-sea trades, up to Wallenius' *Madame Butterfly* of 27,779 dwt carrying 6,200 cars world-wide, though in 2008 the largest vessels on the orderbook were 29,000 dwt with a capacity of 8,000 vehicles. Specialization brought a cost in terms of restricting the cargo to motor cars and light trucks. With the more volatile market of the late 1970s there was a move towards developing vehicle carriers capable of handling a wider range of cargo. The *Undine* (2003) can carry 7200 cars on 13 decks. To carry large, heavy cargoes the stern ramp can carry loads up to 125 tonnes. Decks 4, 6 and 8 are strengthened and their height is adjustable by hoistable sections in decks 5, 7 and 9. This allows bulk parcels of cars to be supplemented by consignments of large vehicles such as trucks, buses, agricultural machinery and heavy plant, which cannot be accommodated between the low-headroom decks of a conventional car carrier.

Cement carriers

Cement is a difficult and dusty cargo to handle, and some specialist cement carriers have been built. Typically they use pneumatic cargo-handling gear with totally enclosed holds and moisture control systems. For example, a 20,000 dwt bulk cement carrier might have four pairs of cargo holds and be designed to handle two grades of Portland cement, with a weight of up to 1.2 tonnes per cubic metre. Shore-based chutes deliver the cement to a single-point receiving system on each side of the ship at a rate of 1,000 tonnes per hour. A dust collection system may also be fitted. The cement is discharged at a rate of 1,200 tonnes per hour using the ship's own cargo-handling gear. Aeration panels in the tank top of each hold fluidize the cargo, allowing it to be pumped out of the hold by blow pumps located in a pump room amidships and discharged to shore-based reception facilities using the ship's boom conveyor. In principle, ships like this can be used to carry any cargo with a fine particle size.

14.5 SHIPS FOR LIQUID BULK CARGOES

The transportation of bulk liquids by sea generally requires the use of tankers. The main types of tanker are for the transport of crude oil, oil products, chemicals, LPG and LNG.

Crude oil tankers

Oil tankers (Table 14.10) form by far the largest fleet of specialist bulk vessels, with over 6,000 vessels, accounting for 37% of the merchant fleet measured in tonnes deadweight. The size of individual tankers ranges from below 1,000 dwt to over 400,000 dwt; up to 1,245 feet (380 metres) in length; up to 222 feet (68 metres) in breadth; and drawing up to 80 feet (24.5 metres) of water.[8] This fleet can usefully be subdivided into six segments: small tankers (under 10,000 dwt), Handy (10,000–59,999 dwt), Panamax (60,000–79,999 dwt), Aframax (80,000–119,999 dwt), Suezmax (120,000–199,999 dwt, and VLCC (over 200,000 dwt). Each of these segments operates as a separate market and, from a ship design viewpoint, each has its own specific requirements.

Table 14.10 The tanker fleet, January 2006

Tanker fleet size					Hull characteristics				Performance	
Size 000 dwt	No.	Total dwt (mill.)	Av dwt	Age 2006	Beam m	Draught m	Capacity 000 bbl	Tanks (number)	Speed (knots)	Fuel cons (t/day)
Small										
1–5	921	2.6	2,783	19	12.7	5.1	19	11	12.2	7.9
5–9	1115	7.7	6,867	16	17	6.8	48	13.6	13	13
Handy										
10–19	728	11	15,051	14	21.7	8.6	106	16.5	14	22.5
20–29	313	8.3	26,611	19	25.5	10.3	201	19	14.7	29.9
30–39	589	21	35,626	13	28.8	11	254	18.1	15.1	37
40–60	740	34	45,895	9	31.8	12.1	320	13.4	14.7	34.1
Panamax										
60–79	325	22.6	69,466	11	32.8	13.4	482	10.9	14.8	39.1
Aframax										
80–120	721	72.9	101,100	10	41.7	14.3	702	10.9	15	46
Suezmax										
120–200	361	54.4	150,673	10	46.7	16.6	1,011	11.9	14.9	62.9
VLCC										
200+	488	142.7	292,412	9	58.4	21.2	2,040	14.2	15.3	85.7
Total/Av.	6,301	377	59,834	12.9	31.7	11.9	518	13.9	14.4	37.8

Source: Clarkson Research Studies, *Tanker Register* 2006, London

The Handy tankers under 50,000 dwt are mainly used for the transport of oil products (see the next section for details) and the larger vessels for the transport of crude oil.

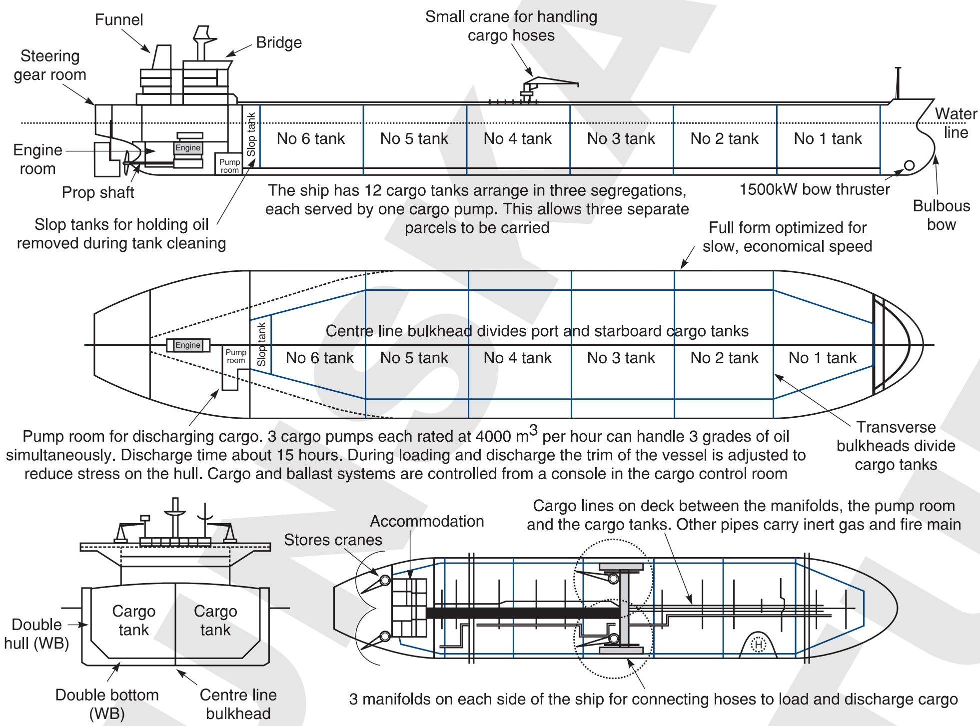
There are two different designs for oil tankers, single hull and double hull. Until the 1990s most crude tankers had a single skin, using the hull as the main containment vessel. The single hull design had longitudinal bulkheads running the length of the ship from the bow to the engine room, dividing the hull into three sets of tanks, the port wing tanks, the centre tanks, and the starboard wing tanks. Transverse bulkheads running across the ship divide these three sets of tanks into separate cargo compartments. In single-hull vessels two or more sets of wing tanks act as 'segregated ballast tanks', which means they are only used for ballast water.

Single-hull tankers are now obsolete. IMO Regulation 13F required tankers ordered after 6 July 1993 to have double hulls as a protective measure against oil loss. A typical arrangement is shown in Figure 14.6. The regulations lay down precise rules regarding the width of the double sides and the double bottom, but the principle is simple enough. There must be a second skin to limit the outflow of oil in the event of collision or grounding damage to the outer hull. In December 2003 IMO passed Resolution MEPC.111(50) to phase out all remaining single-hull tankers by 2010, though it allowed local administrations to permit continued trading on a bilateral basis.

Cargo handling is an important aspect of tanker design. Rapid loading and discharge requires powerful pumps. Crude tankers rely on shore-based facilities for loading, but carry their own cargo pumps for discharge. The pumps are generally located in a pump room between the cargo tanks and the engine room, though tankers carrying different cargo parcels in different holds often have submerged deep well pumps. Pipes running along the deck link the cargo tanks to two banks of manifolds, one on each side of the ship. To load or discharge cargo the manifolds are connected to the shore-based storage tanks by flexible hoses, or fixed Chicksan arms, which are handled by the ship's cranes. The flow of oil is controlled by valves operated from a panel in the cargo control room and must conform to a plan which minimizes stress on the hull – an incorrect load or discharge sequence can literally break a ship in two.[9]

Figure 14.6 shows an example of a 157,800 dwt Suezmax tanker delivered in 2006. This is a medium-sized crude tanker, but the broad design features do not differ significantly for the smaller Aframax and the larger VLCC designs. The tanker has a double skin and scantling deadweight of 157,800 tonnes, with a cargo capacity of 175,000 m^3. However the design of the hull is optimized to a smaller 145,900 dwt, which would allow the ship to carry a 1 million barrel parcel of light (API 30) crude oil. This is a commonly traded parcel size and the arrangement gives the ship the flexibility to carry a full parcel of heavier crude oils than the design standard or extra cargo deadweight if necessary. This arrangement is very common in ships designed for the products trade where some cargoes such as naphtha have a very low specific gravity (see Table 11.5). It is all a matter of deciding what cargoes are likely to be carried and finding the best trade-off between tank volume and design cargo deadweight.

The hull was constructed using 53% high tensile steel, which is relatively high, but the structure was designed for a fatigue life of 40 years, with particular attention paid



Suezmax 157,800 dwt crude oil tanker (87,167 gt)

HULL		MACHINERY		OTHER	
Main Dimensions (m)		Speed & Main Engine		Navigation Equipment	
Deadweight (design)	145,900 dwt	Speed,	15.2 kts 15% sea margin	Radar plant	2
Scantling (scantling)	157,800 dwt	Engine Type	Man B&W 6S70MC-C	Auto pilot/Gyro compass	1
Length over all (m)	274	Power output	22,920 bhp × 91 rpm (16.8 MW)	DGPS navigator	2
Length between perp.	264	NCR (90% DMCR)	20,630 bhp × 87.9 rpm (15.2 MW)	Painting System	
Breadth, moulded (m)	48	D.F.O.C at NCR	60.5 MT/day	Under water hull: epoxy anti-corrosive	
Depth, moulded (m)	23.2	Cruising range	22,900 NM	Antifouling	+ Tin free SPC
Draught (design) (m)	16		Power Supply	Cargo tanks	Tar free epoxy
Draught (scantling) (m)	17	Main generators	Diesel: 3 Sets × 950 kW	Water ballast tanks:	Tar free epoxy
Tank Capacity (m^3)		Emergency generator	1 Set × 300 kW	(Bottom & up to 0.5 m deck head	
Cargo tanks inc. slop	175,000		Steam Generating Plant	and down to 1.7 m only)	
Heavy fuel oil tanks	4,300	Aux. boiler	: 2 Sets × 35 ton/h		
Diesel oil tanks	200	Economizer:	1 Set × 1.8 ton/h	Crew	28
Fresh water tanks	400		Water Ballast System	% high tensile steel	53%
Ballast water tanks	54,500	System	Two main line		
Cargo System		Pump	2 pumps × 2,500 m^3/h × 30m head		
Segregation	Three groups		Vertical centrifugal type		
Pump	3 Sets × 4,000 m^3/h × 135mc		1-Electric motor driven		
Vertical centrifugal, steam turbine driven			1-Steam turbine driven		

Figure 14.6
'Suezmax' crude oil tanker (157,800 dwt) design
Source: Drawing by Martin Stopford, based on design by DSME Shipbuilding Group, S. Korea

to known areas of weakness such as the end connections of the longitudinal stiffeners to the transverse webs and bulkheads. It has 12 cargo tanks plus two slop tanks, arranged in three segregations. Three steam turbine pumps are located in the pump room between the engine room and the cargo tanks. Each pump serves a separate segregation, allowing the ship to handle three grades of cargo simultaneously, which is useful for carrying a combination of smaller parcels and for multi-port discharge. The cargo tanks are coated with tar-free epoxy, another useful extra.

The speed of 15.2 knots on 60.5 tonnes per day is typical for a ship of the size, as can be seen from Table 14.10. Electrical supplies are obtained from three 950 kW diesel generator sets, with one smaller emergency back-up generator and two auxiliary boilers. In addition, a waste heat economizer is fitted, another useful extra to improve fuel efficiency.

A final and less usual feature of a tanker this size is its ice class 1A classification. This means the hull is strengthened and an ice knife is built into the stern. In addition, all deck equipment can operate at –30°C. For example, deck hydraulics are heated to prevent freezing and electric motors are used in preference to air motors. The ice class certification makes the tanker acceptable to charterers for trades where ice is a problem, and is more common on the smaller products tankers, especially those trading in the Baltic. However, new trades are developing, especially out of Russia, where the bigger ships can be used.

Products tankers

Products tankers form a separate category of vessel within the oil tanker fleet, but one which is not clearly defined in statistical terms because the distinction between crude, products tankers and chemical tankers is blurred. Products tankers are similar to crude oil tankers but generally smaller and are divided into clean products tankers, which carry light products such as gasoline and naphtha, and dirty products tankers, which carry the black oils such as fuel oil (see Table 11.5 for details) and a submerged cargo pump in each hold (deep well pumps), allowing separate grades of cargo to be carried on each voyage. Products tankers generally have tank coatings to prevent cargo contamination and reduce corrosion.

Chemical tankers

In Chapter 12 we reviewed transport of chemicals by sea and in Table 12.3 split the fleet into three categories of vessels – chemical parcel tankers, chemical bulk tankers, and chemical/products tankers. These categories, which are mainly based on the number of segregations in the ship, make a good starting point, but when we dig a little deeper we find at least six characteristics of this trade which influence ship design:

- Many different types of chemicals are shipped, including products such as vegetable oils, lube oils, molasses, caustic soda, BTX, styrene and a whole range of specialist chemicals (see Chapter 12).
- Values are high, often over $1,000 per tonne, and the products transported are sensitive to cargo contamination.
- Parcel sizes are small, ranging from 300 tonnes to 6,000 tonnes, with a few larger industrial chemical trades such as caustic soda and MTBE which travel in parcels of up to 40,000 tonnes.

- Small parcels are frequently traded interregionally, and if a small chemical tanker of the appropriate size is used, the freight cost is very high, on a long journey from Europe to the Far East reaching as much as $150 per tonne.
- Some chemicals are corrosive and require special cargo handling and tank characteristics.
- Some chemicals are subject to the IMO regulations on the transport of hazardous cargoes, as discussed below.

Starting with the commodities, the chemicals to be transported vary enormously. The products carried by the chemical tanker fleet were discussed in Chapter 12 and include some bulk chemicals such as naphtha, BTX, alcohols and a large number of specialized chemicals, many of which travel in small parcels and require special handling because of physical characteristics which can damage the ship, the environment or both. In addition, liquid cargoes such as lubricating oils, vegetable oils and molasses fall into this trade group, along with cargoes such as molten sulphur which need much higher temperatures (80°C and above) than other cargoes. As a result, the design of chemical tankers involves many compromises to provide a design which will offer the right balance of cargo flexibility and capital costs.

In addition the ship design must comply with IMO regulations for the carriage of dangerous substances. Carriage of chemicals in bulk is covered by IMO regulations in SOLAS Chapter VII (Carriage of Dangerous Goods and MARPOL Annex II (Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk); see Chapter 16. Both conventions require chemical tankers built after 1 July 1986 to comply with the International Bulk Chemical Code, which gives international standards for the safe transport by sea in bulk of liquid dangerous chemicals, by prescribing the design and construction standards of ships involved in such transport and the equipment they should carry so as to minimize the risks to the ship, its crew and to the environment, having regard to the nature of the products carried. The ship must be capable of dealing efficiently with four hazardous properties of commodities transported: flammability, toxicity, corrosivity, and reactivity. Chemical tankers are classed as being suitable for the carriage of IMO Type 1, Type 2, or Type 3 chemical and oil products, depending on their design characteristics.

All of this leaves the designers juggling characteristics such as cargo tank size and segregations; heating coils; tank coatings; special valve operating gear; and safety systems. In addition to carrying many cargo parcels, chemical tankers tend to load and discharge at several ports, and often different berths within the port. To achieve this flexibility, each cargo tank has a separate cargo-handling system, allowing the ship to carry many small chemical parcels on a single voyage. Vessels operating in liner services on long-haul routes may have 30 or 40 segregated tanks, allowing them to carry a wide range of regulated cargoes. Tank coatings are used to deal with corrosivity and reactivity and three different tank protection methods are used – stainless steel for corrosive cargo and zinc silicate or epoxy coatings which suit most others. Tanks for the most toxic and pervasive substances classified as Type 1 by IMO must be located not less than one-fifth of the ship's breadth from the ship's sides, measured at the water line. All in all it is a complex business for both the investor, who must decide what level of sophistication makes commercial sense, and the designer, who must create a ship which will operate successfully for 20–30 years.

The main features of the sophisticated chemical tanker illustrated in Figure 14.7 will be familiar from the discussion of the crude oil tanker earlier in this section. The ship has a double hull with cargo tanks laid out either side of a corrugated longitudinal bulkhead, separated by corrugated transverse bulkheads. However, this chemical tanker has a number of very significant features which differentiate it from the crude tanker.

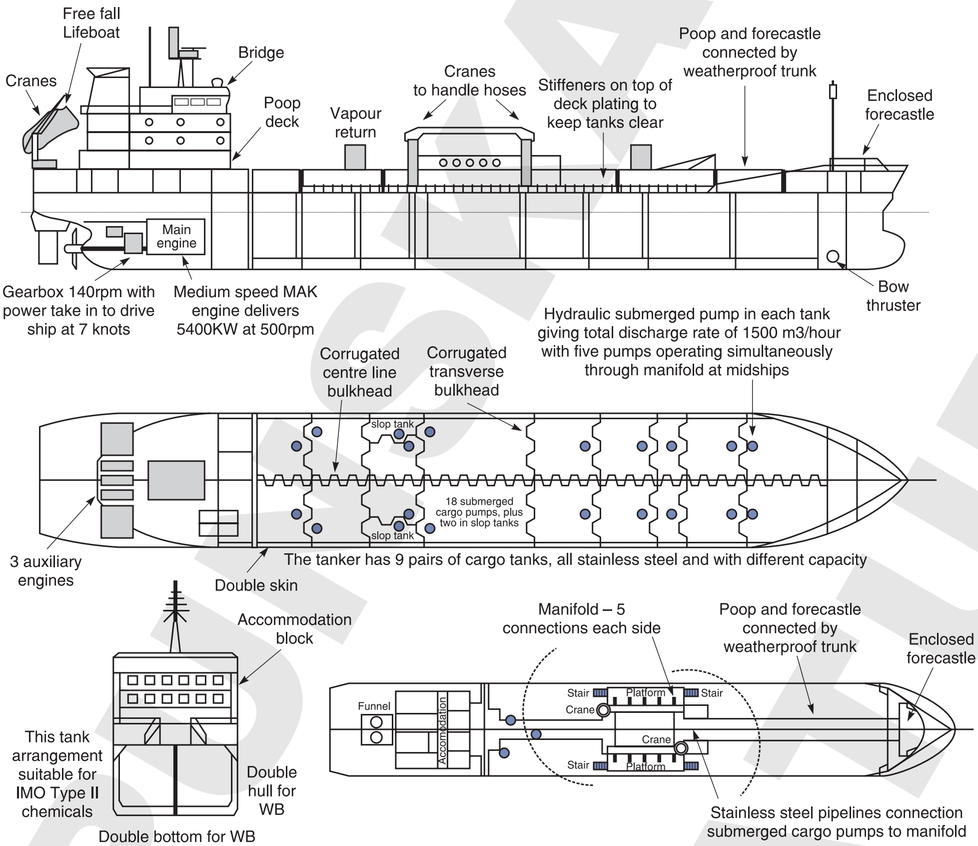
The ship is designed to carry IMO Type 2 cargos in 18 tanks and two slop tanks, all constructed from stainless steel with stiffeners on the outside (for example, they can be seen on the deck), giving smooth internal surfaces for easy tank cleaning and stainless steel heating coils to maintain the cargo at 82°C. Heavy cargoes with a specific gravity of up to 1.55, for example caustic soda, can be loaded in all tanks. Each of the18 tanks has a separate cargo-handling system with its own submerged cargo pump and separate pipelines to the manifold located amidships, where the cargo lines can be connected to hoses leading to storage tanks onshore. There are two cranes to handle the hoses and the manifold has ten hose connections, five on each side of the ship. All the pipes and valves are constructed of stainless steel, and five pumps can work simultaneously to discharge cargo through the five manifold outlets giving a total discharge rate of 1500 m^3 per hour.

Propulsion is provided by a medium-speed diesel engine operating at 500 rpm, with a gearbox which reduces the propeller speed to 140 per rpm. The operating speed is 14.2 knots on 20.5 tonnes of fuel per day, and electricity for ship equipment is provided by three diesel-powered alternators. There is also a shaft generator which provides electricity when the main engine is running. The gearbox also has a power 'take in' which in an emergency can use electricity from the three alternators to drive the vessel at 7 knots, or to top up the power of the main engine.

Since the vessel was designed to operate in the Baltic Sea, encountering ice regularly, it is ice class 1A. In addition to the features mentioned for the crude oil tanker in Figure 14.6, its deck cargo lines and valves are encased in a tunnel running from the poop deck to the enclosed forecastle, an unusual feature, but an interesting example of an owner paying for an extra feature that will make the ship easier and safer to operate in difficult weather conditions. In summary, this is a very sophisticated tanker, designed with specific operating conditions in mind, and the owner made a considerable investment to achieve this performance.

Combined carriers

Combined carriers deserve a section to themselves, if only as an example of the problems facing investors in ships for niche markets (see Section 14.2). To give the ships greater flexibility, oil/bulk/ore carriers (often referred to as OBOs or combined carriers) are designed to carry a full cargo of dry bulk or crude oil. This means the ships can



Chemical Tanker 11,340 dwt

HULL		MACHINERY		OTHER	
Main Dimensions (m)		Propulsion Machinery		Cargo System	
Gtoss tons	7,903 gt	Speed,	14.17 kts 90% MCR	Tank segregations	18 plus 2 slop tanks
Deadweight (design)	9,751 dwt	Engine Type	Caterpillar MAK 6M43	Tanks on deck	2×120 m^3
Scantling (scantling)	11,339 dwt	Power output	5400 kW at 500 rpm	Cargo grades	IMO II and oil products
Length over all (m)	126.2	Fuel Consumption – main	20.5 MT/day	Pumps (submerged)	18 plus 2 slop tanks
Length between perp. (m)	119.2	– auxiliaries	2.9 MT/day	Pump capacity	14×300 m^3/hr and 6×100 m^3/hr
Breadth, moulded (m)	19	Cruising range	9,124 NM	Total discharge rate	1500 m^3 per hour
Depth, moulded (m)	10.7	Prop shaft	140 rpm	Vapour collector for shore return	
Draught (design) (m)	7.6	-shaft generator	1000 kW	2 tank washing appliances per tank	
Draught (scantling) (m)	8.34	-emergency prop motor	1000 kW	Stainless steel heating coils to maintain tanks at 82°C	
Lightweight (tonnes)	4,300	-main engine boost	5,400 kW + 1000 kW	Vertical centrifugal, steam turbine driven	
Tank Capacity (m^3)		Propellor diameter	4,600 mm	Fire extinguishing system	
Cargo tanks	12,120	Power Supply		Fire detection system	
Tank construction	Stainless, inc. pipes	Shaft generator	1000 kW at 1800rpm	Complement	
Heavy fuel oil tanks	550	Diesel alternators	3×660 kW at 900 rpm	Officers	6
Diesel oil tanks	162		3×600 kW at 900 rpm	Ratings	8
Ballast water tanks	4300	Power take-in on gearbox can drive ship at 7 kts		Spare	3
Paint System		Boilers	2×6 ton/h	Total	17
Under water hull: epoxy anti-corrosion				Class: Ice Class 1A	
Antifouling	+ Tin free SPC	Bow thruster	1×600 kW	High tensile steel	8%
Cargo tanks	Tar free epoxy				
Water ballast tanks:	Tar free epoxy bottom & up to 0.5 m, deck head and down to 1.7 m only				

Figure 14.7
Chemical parcel tanker, 11,340 dwt
Source: Drawing by Martin Stopford, based on vessel built by INP Heavy Industries Co. Ltd, S. Korea

triangulate, for example shipping oil from the Middle East to Europe and returning to Asia with a cargo of Polish coal. They could also switch between the tanker and dry bulk markets to take advantage of a rate differential, or to reduce ballast time by carrying dry and liquid cargoes on alternate legs ('triangulation voyages'). In practice, the rewards for flexibility have been slim.

The concept of flexible ships carrying oil on the main leg and returning with a different cargo date back to the early days of the oil trade and in general has not been very successful. The first ocean-going tank steamer, the *Vaderland* (1872), was designed to carry passengers from Belgium to the USA and return with a cargo of petroleum. Unfortunately the owners could not obtain a licence to carry passengers and oil in the same ship so the *Vaderland* ended up carrying general cargo in the petroleum tanks.[10] In the 1920s two ore/oilers, the *Svealand* and the *Amerikaland*, were designed to carry iron ore from Peru to Baltimore, returning with a cargo of oil. This time the plan was frustrated by the high transit charges for the Panama Canal and they never carried oil. However, in the 1950s and 1960s combined carriers achieved greater success, capitalizing on the newly emerging oil and dry cargo trades.

Two different designs were used. The first to enter service in the 1950s were the ore/oilers. These vessels had holds in the centre of the ship to carry high-density iron ore, with side and bottom tanks designed to carry a full cargo of oil. The use of separate compartments avoided the need for cleaning between cargoes, but was wasteful of space and the dry leg was limited to high-density iron ore. The second design, which appeared in the mid-1960s, was the OBO which carried oil or dry bulk in the same cargo spaces. Typically these vessels have double bottoms and holds to carry oil, of which up to six can be used for ore or dry bulk. Hatch covers are oil-tight and gas-tight. Because they could switch between wet and dry markets, they made handsome profits during the three tanker booms in 1967, 1970 and 1973 (see Chapter 2).

So great was the enthusiasm for combined carriers that by the mid-1970s a fleet of 49 m.dwt had been built. Unfortunately this fleet far exceeded the available return cargoes, so the competitive advantage was lost. In addition, the time and difficulty of cleaning the cargo holds when switching between oil and dry cargo made the vessels difficult to charter, especially to oil companies. The resulting indifferent commercial performance of combined carriers was compounded by the fact that the ships were complex to build, maintain and operate, costing about 15% more to run than a comparable tanker or bulk carrier and oil charterers preferred a conventional tanker. In the early 1990s operators of combined carrier fleets were reporting a 10–15% revenue premium (say $2,000–3,000 per day), which paid the extra cost of operating the ship, but left little surplus to cover the higher capital cost. To make matters worse, the large combined carrier fleet ensured that surplus capacity was transmitted between the tanker and dry bulk markets, helping to moderate market peaks. As a result, from the mid-1970s onwards few new ships were ordered and by 2007 the combined carrier fleet had fallen to 8 m.dwt. In retrospect the commercial failure of the combined carrier fleet had less to do with the concept, which was perfectly sound, than with the economic obstacles it faced in a competitive market such as shipping.

14.6 GAS TANKERS

Basic gas tanker technology

Transporting liquid gas by sea presents many complexities, one of which is the number of different cargo systems which are currently in use. So at the outset it is useful to define the various options available. The starting point is the containment system, and there are three options. The first is to use a 'self-supporting' tank system, which sits on a cradle which separates it from the hull. The second is the 'membrane' system which moulds the tank to the hull, which provides its strength, with insulation sandwiched between the tank membrane and the hull. The membrane must be able to cope with extreme temperature changes. The third option is the 'prismatic' system, which is a hybrid, using self-supporting tanks with an inner and outer skin, but tied into the main hull structure. Although the design details vary enormously, all gas tankers fall into one of these categories.

The gas is liquefied onshore prior to loading and there are three ways to keep it liquid during transport: by pressure;[11] by insulating the tanks; or by reliquefying any gas which boils off and returning it to the cargo tanks (petroleum gas remains liquid at around –48°C). In practice it is all a matter of economics, and various different permutations of refrigeration and pressure are used. Some small LPG tankers rely entirely on pressure, but this is uneconomic for large cargo parcels which use an on-board refrigeration plant to reliquefy boil-off gas and return it to the cargo tanks. Prior to 2006 LNG tankers did not carry refrigeration equipment, relying entirely on speed and heavy insulation to minimize the boil-off. Any burned-off gas was burnt in the ship's boilers.

Liquid petroleum gas tankers

The term 'LPG tanker' is confusing because gas tankers carry a mix of petroleum gases such as propane, butane and isobutene and chemical gases such as ammonia, ethylene, propylene, butadiene and vinyl chloride. Most of these gases liquefy at temperatures ranges from –0.5°C to –50°C (see Table 12.4), but some liquefy at much lower temperatures (e.g. ethylene at –103.9°C). Gas tankers must be able to maintain gas at the required temperature during transport. In addition to temperature, the volume of cargo and the distance over which it is transported are also important. For example, LPG is shipped in large volumes on long-haul routes, especially from the Arabian Gulf to Japan, and the biggest LPG tankers are built for these trades. From a design viewpoint the LPG tankers in common use can be divided into four groups, depending largely on the size of the cargo being shipped.

Fully pressurized vessels carry liquefied gas in pressure tanks strong enough to prevent the gas cargo regasifying, even at ambient temperatures – typically 20 bar is required. The tanks are very heavy and this method is mainly used for small LPG tankers. In 2006 there were 540 pressurized vessels in the gas fleet, ranging in size from 100 to 11,000 m^3. LPG and anhydrous ammonia are the most common cargoes, and the design pressure is optimized for propane at about 18 bar. Pressurized tankers have two to six cylindrical carbon steel pressure vessels resting on saddles built into the hull, or on deck. Cargo is carried at ambient temperature, and a compressor is usually provided to pressurize the cargo tanks during discharge or to transfer the cargo vapour when loading or discharging. Cargo handling is important because these short-haul ships make many port calls in a year. Because the cylindrical pressure tanks use the under-deck space inefficiently and are heavy, with a cargo to tank weight ratio of about 2 : 1, this system is mainly used for smaller ships.

Semi-refrigerated vessels have pressurized tanks constructed of carbon steel (typically 5–7 bar) with insulation to slow the boil-off and refrigeration plant to reliquefy the gas that escapes and return it to the tanks. These lighter-pressure vessels are located inside the hull (the cargo to tank weight ratio is typically about 4 : 1), and this is the preferred system for medium-sized LPG tankers. There were 280 semi-refrigerated ships in 2006, ranging in size from 1,000 to 30,000 m^3. Depending on ship size and specification, the cargo is carried at minimum temperatures of about −50°C. Cargo handling is an issue, and when cargoes are loaded from fully pressurized storage tanks on shore it may also be necessary to refrigerate the cargo during loading by drawing off the vapours from the top of the tank. This process usually determines the size of the refrigerating plant if a reasonable loading rate is to be maintained.

Fully refrigerated vessels are generally built for the long-haul trades. In 2006 there were 197 fully refrigerated LPG vessels, ranging in size from 1,000 m^3 to 100,000 m^3. For example, a typical 82,276 m^3 LPG tanker delivered in 2003 was 224 metres in length with a service speed of 16.75 knots. LPG weighs 0.6 tonnes per m^3, so it was only 59,423 dwt with a draft of 12.6 metres (a similar sized crude oil tanker would be 87,000 dwt with a draft of 15.6 metres).[12] Cargo is carried at –46°C in unpressurized free-standing prismatic cargo tanks built of heat-treated carbon steel or alloy with centre line and transverse bulkheads to prevent 'sloshing'. The space between the hull and the tanks is insulated. Refrigeration plant reliquefies the boil-off gas and a cargo heater may also be fitted for discharging to storage tanks not constructed of low-temperature materials. The liquid gas is discharged through thermally insulated land-based pipes using the ship's pumps.

Ethylene an important intermediate product of the petrochemicals industry, which liquefies at −104°C and usually travels in small *ethylene carriers* ranging in size from about 2,000 m^3 to 30,000 m^3 (see Section 12.3). These are sophisticated vessels and some can carry ethane, LPG, ammonia, propylene butadiene, vinyl chloride monomer and even LNG. The tanks are insulated and may be self-supporting, prismatic or membrane type. Impurities such as oil, oxygen and carbon dioxide must be kept within acceptable limits when pumping, refrigerating, purging and inerting the gas cargo.

The choice between these four systems is a trade-off between the initial cost, cargo flexibility and operating cost, but the pressurized system is generally more economic for small ships and refrigeration for big ones. Broadly speaking, petrochemical gases are transported in semi-refrigerated or fully pressurized vessels under 20,000 m^3, and LPG and ammonia gases are transported in fully refrigerated vessels, ranging in size from 20,000 to 80,000 m^3, for long-haul, large-volume transportation. Some semi-refrigerated vessels can carry ethylene (−104°C) and ethane (−82°C); and in a few cases LNG. To a lesser extent, these smaller vessels are sometimes used to transport LPG and ammonia over short-haul routes, where the fully pressurized vessels mainly operate.

Liquefied natural gas tankers

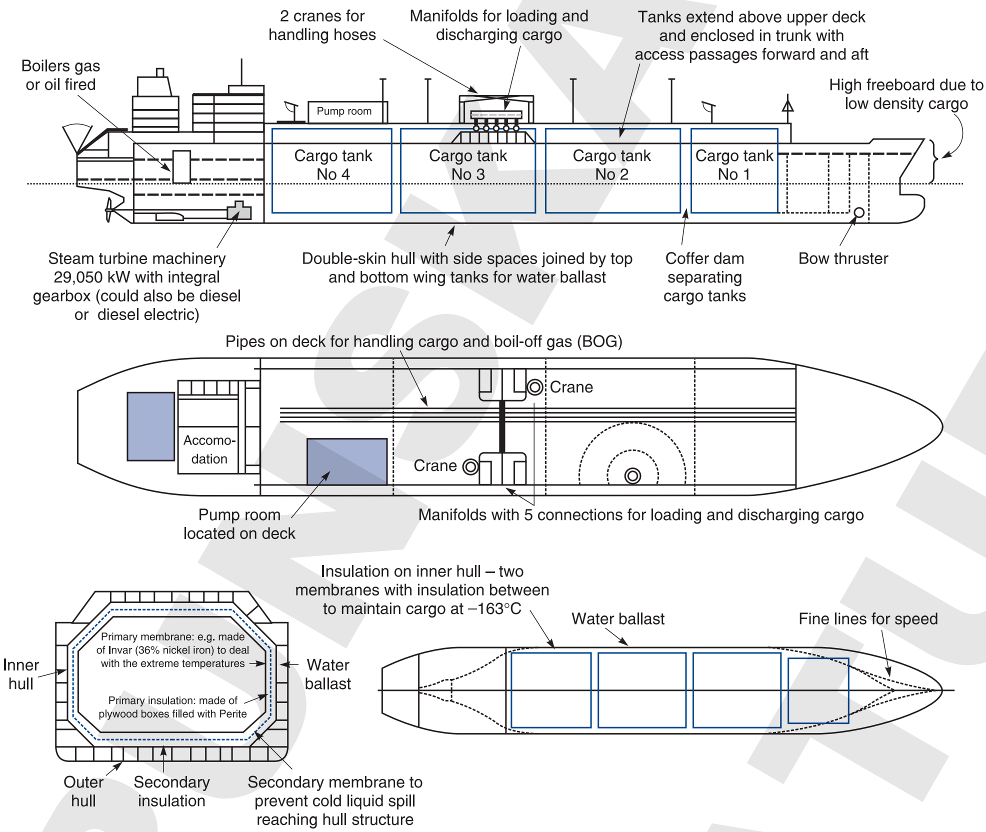
Natural gas is primarily an energy source. It is a high-volume commodity and very price-sensitive, so the cost of transport plays a major part in the trade's economics and ship design. LNG tankers generally form part of a carefully planned gas supply operation involving a substantial investment in shore-based liquefaction and regasification facilities. In 2007 there was a fleet of 240 vessels, with another 140 on order. These are the biggest gas tankers and in 2007 they ranged in size up to 153,000 m^3, with a new generation of 270,000 m^3 vessels on order for the long-haul Middle East to USA trades.

Natural gas liquefies at −161.5°C, at which temperature it is reduced to 1/630 times its original volume. However, this low temperature raises various issues for the ship designer. Before loading, the methane gas is liquefied by refrigeration in the terminal (the plant which does this is called a 'train') and pumped into the ship's insulated tanks at atmospheric pressure. Apart from keeping the gas at the required temperature, the tank system must be able to deal with the large temperature changes which occur when cargo is loaded and unloaded. LNG tankers rely on insulation and up to 0.3% of the cargo boils off per day. In the past LNG tankers did not reliquefy this gas as LPG tankers do, because of the high power required to do this.[13] Instead they burned it in the ship's boilers, which explains why steam turbines survived so long in this trade. Although less efficient than diesel engines, the boil-off provided 75% of the daily fuel consumption of a 75,000 m^3 vessel, making this an economic solution. However, the first LNG tankers with medium-speed diesel engines were delivered in 2006, and ships with reliquefaction plant and conventional slow-speed diesel engines in 2007.

Self-supporting, membrane and prismatic tank systems are all used for LNG tankers. The Moss system uses distinctive self-supporting spherical tanks with a single insulation layer. The membrane tank system offered by Gaz Transport has a primary and secondary thin membrane made of Invar (36% nickel iron) with insulation constructed of plywood boxes filled with Perlite, whilst the Technigaz system uses a stainless steel membrane. The two companies merged in 1994. IHI offers a prismatic system. In 2003 the Moss system had a 51% market share, whilst Gaz Transport had 37% and Technigaz 11%.

An example of an LNG tanker using the membrane system is shown in Figure 14.8. The vessel has a double skin with top and bottom wing tanks to carry water ballast. There are four cargo tanks separated by coffer dams and constructed in accordance with the GTT Mark 3 containment system for the carriage of LNG cargos. The tanks extend above the deck and are enclosed in a trunk which provides both protection and access passages.

The cargo tanks are moulded to the inner hull of the ship and insulated by the four-layer system described in previous paragraphs. A primary membrane protects the primary insulation, behind which is a secondary membrane and the secondary insulation which is attached to the ship's inner hull. With this level of insulation the boil-off gas is restricted to 0.15% of the cargo volume, and this is burnt in the ship's engine. However, some recent designs have reliquefaction equipment and return the gas to the cargo holds. It is all a matter of economics. The liquid gas is discharged using the ship's



LNG Tanker 145,600m^3

HULL		MACHINERY		OTHER	
Main Dimensions (m)		Propulsion Machinery		Cargo System	
Deadweight (design)	71,450 dwt	Speed,	20.6 kts 85% MCR	Cargo tanks	4 IMO Type 2 Membrane
Scantling (scantling)	81,450 dwt	Engine Type	Steam turbine	Pump type	submerged electric
Gross tons	95,508 gt	Power output	39,500 hp, 29,050 kW	Pump capacity	8×1800 m^3/hr
Length over all (m)	283	Main boilers	2×66 tonnes sleem/hour	Discharge rate	12,100 m^3/hour
Length between perp.	270	Consumption – main	171.1 MT/day	Boil off rate per day	0.15%
Breadth, moulded (m)	43.4	Cruising range	9,124 miles		
Depth, moulded (m)	26	Prop shaft	90 rpm	Bow thruster	1×2500KW
Draught (design) (m)	11.4	Propellor diameter	8,600 mm fixed pitch	Complement	
Draught (scantling) (m)	12.4	Power Supply		Crew	41
Lightweight (tonnes)	30,740	Turbo alternators	2×3450 kW at 1800 rpm	Suez crew	6
Tank Capacity (m^3)		Diesel alternator:-			
Cargo tanks	145,600	- engine	1×3664 kW at 720 rpm		
Tank construction	GTT Membrane	- alternator	1×3450 kW at 720 rpm		
Heavy fuel oil tanks	7,490				
Diesel oil tanks	440				
Ballast water tanks	57,000				

Figure 14.8

LNG tanker design with membrane tank system, 145,600 m^3 capacity, with steam turbine

Source: Drawing by Martin Stopford, based on vessel built by Samsung Heavy Industries Co. S. Korea eight submerged electric cargo pumps, each with a capacity of 1700 m^3 per hour, and the cargo can be discharged in 12 hours.

Propulsion is provided by a traditional steam turbine system. Two water tube boilers, which burn fuel oil or boil-off gas, provide steam to a reversible steam turbine engine. The gearbox is integrated with the turbine, outputting 91 rpm to the propeller. The service speed of the ship is 20 knots and the consumption is 171 tons of fuel oil per day. Although turbines are the traditional power source for LNG tankers, diesel engines and diesel electric systems are also used.

This LNG tanker is a very sophisticated and expensive vessel, but the broad features are similar to the other tankers discussed in this chapter. The big difference is the engineering skills, materials and technology required to load, transport and discharge a liquid cargo at a temperature of −161.5°C.

14.7 NON-CARGO SHIPS

Non-cargo and service vessels cover a wide variety of ships from a 200 grt tug to a 100,000 gt cruise liner. This makes it difficult to analyse the demand for each type with any authority. Although these vessels represent only 7% of the fleet in gross tonnage terms, they are much more important to the industry in value and number. Over 70% of non-cargo carrying vessels may be under 500 gt, but by number they make up nearly half of the world's shipping fleet.

The fishing fleet

Fishing vessels account for nearly half the non-cargo carrying fleet by tonnage. The fleet includes both fishing vessels and fish factories. The world fishing fleet grew rapidly at 15% per annum in the 1960s and then started to stabilize in the face of overfished oceans, escalating costs and the uncertainty of offshore limits.

Supply ships and service craft

Supply ships and service vessels such as anchor handling tugs are used in the offshore oil and gas industry, and in July 2007 there was a fleet of 4394 of these vessels. With the increasing depth and distance from shore at which the work is taking place, proportionally more and larger vessels are needed. There has also been a trend towards building more highly powered, sophisticated, MPP vessels, especially for use in the bad weather areas of the North Sea and Gulf of Alaska.

Tugs and dredgers

Tugs, dredgers and research craft form part of the fleet related to the coastal seabed activity, and there has also been a growing demand from harbour and canal authorities. One of the reasons for the faster growth was the change in trading patterns towards the developing countries and the use of larger ships. The growing interest in the resources of the seabed also generated a growing market for research, survey vessels and icebreakers.

14.8 ECONOMIC CRITERIA FOR EVALUATING SHIP DESIGNS

So far we have discussed the options that may confront a shipowner contemplating an investment decision. For the many practical reasons discussed, it is not easy to evaluate these options in financial or economic terms, and there is a temptation to suggest that ship design is a matter for commercial flair or 'gut feeling' rather than rigorous economic analysis. But despite this the commercial world expects such major investment decisions to be supported by some form of economic analysis.

There is substantial literature on the evaluation of alternative ship designs.[14] For practical purposes, the analysis needs to be carried out at two levels, which we will refer to here as market research and financial analysis.

Market research

Market research is concerned with analysing the economic performance of the ship within the company's overall shipping activities. For a charter market operator this analysis might involve an examination of the type of vessel that will be easy to charter and its potential resale value. A liner operator might study the size of ship required to handle changes in the pattern of trade or competition on major routes and features such as speed and reefer capacity. This is closely aligned to the market research analysis described in Chapter 17. Through market research the owner can develop a specification for the type of shipping operation in which the vessel is to be used and the performance parameters that the vessel must satisfy.

Financial analysis

The next step is to identify the ship design that meets the performance requirements most effectively, using some form of financial measure of merit. For example, the designer may be told that the owner requires a product tanker with the following features: a draught of not more than 10 metres; a length of not more than 170 metres; ability to carry simple chemicals such as caustic soda; cargo tanks that are cheap to clean; an operating speed of 14 knots; and design optimized to a 40,000 ton cargo of naphtha, but capable of carrying a 45,000 dwt of denser cargo. Although this list of requirements appears to be highly specific, in practice there may not be a unique solution. On examination, it may transpire that some of the requirements are inconsistent or very difficult to achieve. For example, it may be difficult to achieve the design draught within the other specified parameters, or doing so may result in a vessel with poor fuel economy. Did the shipowner appreciate this when he laid down the specification and is he prepared to pay the cost? These are all issues that have to be tackled at the operational analysis stage.

The task of the ship designer is to evaluate the various options in economic terms to see which gives the best overall result, recognizing both cost and operational performance. Buxton suggests two different ways of doing this, depending on the circumstances, net present value and required freight rate.[15]

The net present value technique, which is discussed in Section 6.7, involves setting up a projected cashflow for each of the options under consideration. Revenues and costs are projected on an annual basis over the life of the ship and the net cashflow in each year is calculated, taking account of capital payments, trading income, expenditure, taxation (if any) and probably the final resale value of the vessel. These annual cashflows are then discounted back to the present (using a minimum acceptable rate of return, for example 10% per annum) and summed, giving the NPV of each of the options. The option giving the highest NPV is generally preferred.

The advantage of this method is that it takes account of both the cost and revenue flows and produces a single figure, which makes the comparison of options a simple matter. On the negative side, if the revenue flow is difficult to predict, especially for vessels trading on the spot market, with the results that some near-arbitrary assumption about the potential earning power of the vessel is made, this can distort results. For this reason, the NPV approach is most appropriate when evaluating ships being constructed for a long-term time charter.

The required freight rate method avoids the problem of predicting revenue by comparing the relative unit transport cost of different ship types. The RFR is calculated by computing the annual average cost of running the ship (operating plus voyage costs), adding the capital costs and dividing by the annual tonnage of cargo transported to calculate the cost per tonne of cargo. These costs can then be discounted in exactly the same way as the NPV calculation and a discounted RFR calculated. There are several different ways of carrying out this calculation, but all aim to show which ship design will give the lowest unit transportation cost within the parameters specified by the owner. It is left to the investor to weigh up whether the project has a reasonable chance of earning enough revenue to cover the RFR. This may be an absolute evaluation, or used for comparing alternative designs or investment projects. For example is it better to order a new floating production, storage and offloading system or to buy a second-hand tanker and convert it? Although there are many very subjective variables in such an analysis, the process of working through the financial comparison can help to clarify the decision.

There are several variations on these two methods, notably the yield or internal rate of return, which is closely related to the NPV method (being the interest rate that produces an NPV of zero), and the permissible price (i.e. the maximum price payable for a ship to yield the required rate of return), which can be derived from either method.

14.9 SUMMARY

This chapter has reviewed the ships used in the shipping business. We started with two important observations. First, because the demand for merchant ships is derived from the demand for transport, we cannot determine the demand for merchant ships simply by examining the cargo flows. Shipowners are free to use whatever ships they think will provide the service most profitably. We must consider a wider range of economic factors which include the type of cargo, the type of shipping operation and the owner's commercial philosophy. Second, ship types should not be viewed in terms of physical design characteristics. From the shipowner's point of view, ships of the same type are substitutes in the market place. In particular, size plays an important part in determining ship type.

An examination of the relationship between cargo units and ship types shows that some ships, such as the MPP cargo liners or ro-ros, are highly flexible and capable of carrying six or seven different types of cargo units, while others, such as the containership, the gas carrier or the crude oil tanker, are highly specialized and are capable of carrying only one cargo. In terms of the revenue maximization calculations described in Chapter 3, the flexible ship has a better chance of achieving a high level of loaded days at sea and deadweight utilization because it is capable of carrying many different cargo types. The cost of this flexibility occurs in terms of higher capital cost per unit of capacity and, in some cases, lower operating efficiency than the more specialized vessel. Recently the trend has been decisively towards specialized ships with low LCM ratings.

In the liner business, the three main types of purpose-built vessels are containerships, MPP cargo ships and ro-ros. Most of the ships employed in the liner trades are purpose-built within these general categories. There used to be an enormous number of different and unique ship specifications designed to fit particular trades, but containerization has brought a high degree of standardization to ships used in the liner trades. There are still a few ships in the fleet designed for cargo flexibility, notably the MPP ships which can carry general cargo, project cargo, containers and even dry bulk. The popularity of these ships with investors declined during the 1980s, but the fleet has started to grow again.

In the dry bulk market, the trend towards single-purpose vessels continues. The general-purpose bulk carrier dominates the business, despite being restricted to the carriage of dry bulk cargoes and specialized bulks such as forest products and steel products. More flexible dry bulk vessels are the 'tweendecker which can trade either in bulk or general cargo; the open-hold bulk carrier which can trade in homogeneous dry bulk; containers and specialized bulks such as forest products; and the combined carrier which can alternate between dry bulk and crude oil and other liquids. All have been losing market share, especially the combined carrier.

Finally, there is a range of specialist ships designed for the bulk transport of specific cargoes. The most prominent of these are liquefied gas carriers, refrigerated cargo ships, car carriers, heavy lift ships, and cement carriers. In some cases, such as gas carriers, these ships are totally specialized and are in competition only with other ships of the same type, whereas others, such as the refrigerated cargo ship, the car carrier and the heavy lift vessel, face competition from MPP vessels.

The key point in all of this is that most cargoes can be transported in several different types of ship. In the last resort, the ship in which the cargo travels is determined by commercial performance rather than its specific technical design characteristics.