Characteristics and Cost Structure of the Bulk Shipping Fleet

Occasional Paper

The Paper presents an analysis of the changes in the size and distribution of the world fleet over the period 1970 to 1987. A comparison of the world fleet and bulk ships visiting Australia in 1985-86 is also presented. Also included is a forecast of the future size and distribution of the world fleet under a range of assumptions. Australia's export of major bulk commodities in terms of volume (coal, iron ore and grains) is dependent on the services provided by the world dry bulk fleet. This Paper provides an analysis of the supply characteristics of these ships.

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Characteristics and Cost Structure of the Bulk Shipping Fleet

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ABSTRACT

Australia's export of major bulk commodities in terms of volume (coal, iron ore and grains) is dependent on the services provided by the world dry bulk fleet. This Paper provides an analysis of the supply characteristics of these ships.

The Paper presents an analysis of the changes in the size and distribution of the world fleet over the period 1970 to 1987. A comparison of the world fleet and bulk ships visiting Australia in 1985-86 is also presented. Also included is a forecast of the future size and distribution of the world fleet under a range of assumptions.

A regression analysis was made to relate the principal dimensions of bulk ships and fuel consumption to ship size as measured by deadweight tonnes and trends examined.

The influence of the Panama Canal on ship design characteristics is also included in the analysis. Possible technological change in bulk ship propulsion systems and the development of self-unloading ships is discussed.

There is currently a lot of activity among developed maritime countries to reduce crew costs. There are two approaches to this issue, the first is to register the ship with a registry which allows the use of low cost third world crews and the second is to use technology to reduce manning levels. The Paper discusses both of these approaches as well as comparing the costs of Australian crews with those of other maritime countries.

A model of bulk ship operating costs is developed to illustrate the costs of different shipping tasks. The tasks analysed include the costs of triangular route patterns compared to a shuttle service, two port loading and the use of self-unloading ships. The results of the analysis are presented in terms of break even freight rates.

FOREWORD

In the past ten years the world bulk shipping industry has been undergoing profound changes in market structure. The industry has been shaped by changes in the nature, volume and pattern of world trade, growth of competition from developing countries and accelerating technological change, resulting in advanced bulk ships powered by more efficient engines and operated by smaller crews.

Given the importance of bulk shipping to Australia's economy and the necessity to adapt to the changing industry environment, the Department of Transport and Communications (DoTC) requested the Bureau of Transport and Communications Economics (BTCE) to conduct a study of the structure and underlying trends in the supply-side of the industry. These trends are important determinants of investment alternatives in bulk ships as well as port infrastructure. To identify opportunities for increased cost efficiencies, detailed analyses of operating cost components were made and a useful cost model applicable to different trading situations produced.

The study team was directed by Mr N. Gentle while Mr M. Pascoe, Mrs B. Dziatkowiec, Miss K. McLennan and Mr T. Mikosza made significant contributions. The team members would like to acknowledge the interest, support and co-operation of the individuals and organisations approached by the Bureau seeking information and comment on the draft Paper. We trust this study will be a catalyst for further consideration of issues of concern to bulk shipowners, shippers' unions and policy makers.

M. HADDAD
Director

Bureau of Transport and Communications Economics
Canberra
January 1989

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SUMMARY

Three of Australia's major export earners in recent years have been coal, wheat, barley and iron ore. In fact, 206 million tonnes of these four commodities were exported during 1987-88, earning approximately $10 000 million for Australia, or 21 per cent of our total export earnings. These primary products were shipped overseas by dry bulk and ore carriers. Therefore, an efficient and reliable bulk shipping service is vitally important to Australia's international trading position.

This study examines the supply-side characteristics of the bulk shipping industry. The Paper is divided into four parts:

- a descriptive and comparative analysis of the world dry bulk fleet and the fleet which called at Australian ports during 1985-86, by size, age and flag of ships;
- a description of technological developments within the industry;
- a detailed examination of the operational cost components of today's trading bulk carriers, leading to the construction of an operating cost model; and
- the application of the derived cost model to hypothetical trade routes.

The world bulk fleet changed markedly between 1970 to 1987. The size of the fleet increased from 55.1 million deadweight tonnes in January 1970 to a peak of 197.5 million deadweight tonnes in January 1986. There was a small decline to 196 million deadweight tonnes in January 1987. Over the same period, the average ship size increased from 28 000 deadweight tonnes to 41 000 deadweight tonnes. The large number of newbuildings since 1980 has kept the average age of the fleet to a relatively low 9.2 years (Chapter 2).

The proportion of the fleet registered under flags of convenience (FOC) has stayed fairly constant at around 30 per cent. However, the share registered with traditional maritime countries has declined. A

diminishing proportion of shipowners operate within the dry bulk spot market. This has much to do with financing arrangements for newbuildings and cargo reservation policies (Chapter 2).

Dry bulk ships which visit Australia tend to be larger and newer than the world fleet. The larger ships visiting Australian ports in 1985-86 were more likely to be registered in OECD countries. FOC registered ships were more prevalent among the smaller sizes. The larger dry bulk ships were mostly employed in the export of iron ore and coal. Grain exports were generally carried in small ships with 62 per cent being exported in ships of less than 40 000 deadweight tonnes. This is a much higher proportion than experienced by other major grain exporters (Chapter 3).

Forecasts were made of the future distribution and size of the world fleet under a range of assumptions. Common conclusions of the forecasts are that there will be only moderate growth in the total size of the world fleet with very large ships expected to increase significantly their share (Chapter 4).

Some of the conclusions drawn from the analysis of bulk ships technology are that, for vessels of all tonnages, there has been a trend towards wider ships of shallower draught, shorter length and lower engine power requirements. Reduced power requirements which are especially significant for larger vessels have been achieved through more efficient hull and propellor designs and superior hull coatings. Significant improvements in fuel efficiency of marine engines have also been achieved. Other forms of technological change, in particular, wind assisted vessels and self unloaders, as alternative means to reduce operating costs, are considered (Chapter 5).

There is currently a lot of activity among maritime countries to reduce crew costs. There are two ways of approaching this issue. First, many shipowners switch flags to a registry which allows the employment of low cost Third World crews. This is one of the major reasons behind the decline in the number of ships registered in the traditional maritime countries. Second, new technology is being introduced into modern ships to allow the use of smaller crews and usually requires the multi-skilling of crews and removal of many of the distinctions between deck and engineroom crew. Crews can be reduced to within the range of 17 to 19 through the introduction of a moderate amount of new technology such as automated engine rooms. Crews of this size are now common in developed countries. New Australian ships using this approach have reduced crew sizes to 26 and more recently to 21. Reduction of crew sizes below the 17 to 19 range requires the use of more advanced labour saving technology. Ships using this technology with crew sizes of 12 to 14 are now in use on an experimental basis (Chapter 6).

International crew cost comparisons are complex and are valid only if all components of earnings and on-costs are included. Estimates of total 1986 annual costs per berth in US dollar terms, which take into account all direct and indirect crew cost components as well as social security costs, rank Australia near the level of traditional maritime nations. Examples of estimated annual crew costs per berth and total crew costs calculated at rates of exchange existing on 2 September 1986 are given in the following table.

ESTIMATED ANNUAL CREW COSTS FOR SELECTED FLAGS, 1986

Flag	*Crew cost per berth (US$)*	*Crew complement*	*Total crew costs (US$'000)*
Australia	56 000	26	1 456
	57 300	21	1 203
Japan	87 400	18	1 573
Norway	64 000	18	1 152
Open registries	15 000	33	495

It will be seen from these results that, although Japanese crew costs per berth are 56 per cent greater than Australian costs per berth, in total ship terms they are only 8 per cent greater because of significant crew complement differences. Calculations based on Australian ship complements of 21 reduce total ship costs by more than US$200 000 per annum, substantially improving the Australian flag's cost competitiveness (Chapter 7).

A model of bulk ships' operating costs developed in Chapters 8 and 9 is applied to four hypothetical bulk shipping tasks in Chapter 10. In all tasks, break even revenue requirements per tonne are calculated on free in and out terms, that is, stevedoring charges are excluded. Some of the main results are:

- Significant savings can be achieved through the use of triangular routes involving two-load legs compared to a shuttle task on one of the load legs. For example, an Australian crewed 150 000-deadweight tonne ship trading on a triangular route of a total length of 11 000 nautical miles has a break even freight rate 13 per cent lower than a FOC ship of the same size undertaking a shuttle task on one of the loaded legs (total 9000 nautical miles). The savings increase to 25 per cent if the triangular route is increased to 25 500 nautical miles and the shuttle task to a total distance of 20 000 nautical miles.

- Two-port loading has significantly lower costs than the use of a smaller ship which can fully load at the draught-restricted port. Deepening the draught-restricted port to allow larger ships to load fully, thus eliminating the need for topping up, would reduce the breakeven freight rate by close to $1 per tonne.
- Self-unloading bulk carriers are costed showing potential savings of 5 to 10 per cent compared with conventionally loaded vessels of the same capacity on identical tasks. The savings are increased if larger self-unloaders can be substituted for smaller conventional ships.

Four major points can be drawn from the study. First, Australian exports of iron ore and coal are well served by the dry bulk shipping industry. The ships used tend to be large and relatively new, thus achieving economies of size and the benefits of new technology. Grain exports are the exceptions and are missing out on economies of size with a disproportionate amount of grain exports being in small ships compared to world trends in this trade.

Second, bulk ships are tending to become broader and shallower to allow maximum carrying capacity from draught-restricted ports. The *Iron Pacific* is one Australian ship that has taken advantage of this development in ship design. The use of larger ships also means that Australian crew cost disadvantages are reduced.

Third, Australian crew costs per berth are comparable to berth costs experienced in other developed countries both in absolute terms and in comparison to labour costs in other sectors of the economy. The main disadvantage faced by Australian shipowners is crew size. Although Australian crew sizes have been reduced substantially to 26 in 1986, and more recently to 21, they are still higher than those commonly employed in other OECD countries. If Australian crew sizes were closer to those in other advanced countries, then relatively new second-hand ships could be purchased and adapted to Australian conditions at much lower cost than is now the case.

Fourth, adoption of triangulation routes and possibly use of self-unloaders can confer benefits to Australian shipping through the better utilisation of ships and reduced port costs (in the case of self-unloaders).

CHAPTER 1 INTRODUCTION

Australian exports are dominated by primary products exported in bulk carriers. In 1987-88, 206 million tonnes of the four primary products, coal, iron ore, wheat and barley, were exported. The value of these products was $8500 million or 20.8 per cent of the total value of Australia's exports in that year (ABS 1989).

By any measure, this export task is a major operation for the bulk shipping industry. It is a diverse task employing generally smaller ships (less than 40 000 dwt) for the export of grain and some of the largest ships in the world in the export of coal and iron ore. Clearly, the bulk shipping industry is of major importance to Australian exports.

This Paper examines the bulk shipping industry from three supply-side perspectives. First, the characteristics of the bulk shipping fleet are examined. The distribution of the world fleet and recent trends are discussed in Chapter 2. Chapter 3 discusses the fleet of ships which visit Australia and the differences from the world fleet. Some forecasts of the future development of the world fleet are presented in Chapter 4.

The second perspective is an examination of the trends in bulk ship technology. Chapter 5 presents statistical analyses of past trends and discusses future possibilities. Chapter 6 discusses the relationship between technology and crewing levels.

The third perspective examines bulk shipping costs. The major costs of crew and capital are discussed in Chapters 7 and 8. Chapter 9 draws all the costs together and presents a model of bulk ship operating costs. This model is applied to a number of bulk ship trading patterns in Chapter 10

The final chapter presents a number of conclusions derived from the analyses discussed in earlier chapters.

CHAPTER 2 DISTRIBUTION OF THE WORLD FLEET

The world bulk carrier fleet grew strongly between 1970 and 1986. From January 1970 to January 1980 the fleet grew at an average annual rate of 9.6 per cent from 55.1 million deadweight tonnes (dwt) to 137.7 million dwt. From January 1980 to January 1986 the fleet experienced a lower growth rate of 6.2 per cent reaching a total of 4968 ships and 197.5 million dwt. This trend was reversed in 1986 when the fleet showed a decline, so that in January 1987 there were 4790 bulk ships totalling 196 million dwt and 4651 ships totalling 193.9 million dwt in July 1988 (Fearnleys 1988, 4). The bulk fleet has been undergoing gradual change in terms of its size distribution and, in recent times, a significant change in terms of its distribution by country of registry, or flag.

The objective of this chapter is to examine changes in the size and registry of the world bulk carrier fleet. Some of the results are used in the cost analysis presented in subsequent chapters. The results also carry implications for future Australian port development plans and for more direct participation by Australia as a shipowner nation.

DISTRIBUTION BY SIZE

Table 2.1 and Figure I.1 show the distribution by size of the bulk fleet for selected years from 1970 to 1987. During this period the proportion of large ships has increased significantly. In 1970 only 0.3 per cent of ships was larger than 100 000 dwt. By January 1987 this proportion had increased to 6.1 per cent. At the other end of the spectrum, the proportion of ships less than 18 000 dwt declined from 30 per cent in 1970 to 11.6 per cent in 1987.

The proportion of ships in the range 18 000 to 60 000 dwt has remained relatively stable increasing from 69.5 per cent in 1975 to 70.7 per cent in 1987, while the proportion of vessels in the range 60 000 to 80 000 dwt has trebled between 1970 and 1987 from 3.5 per cent to 10.5 per cent.

TABLE 2.1 DEVELOPMENT OF THE SIZE DISTRIBUTION OF THE WORLD BULK FLEET

Size ('000 dwt)	*Number of ships*[a]				
	1970	*1975*	*1980*	*1985*	*1987*
0-10	na (0.0)	na (0.0)	na (0.0)	na (0.0)	na (0.0)
10-18	591 (30.1)	652 (21.8)	760 (18.9)	665 (13.7)	557 (11.6)
18-40	1 025 (52.2)	1 706 (57.0)	2 326 (57.9)	2 822 (58.1)	2 755 (57.5)
40-60	267 (13.6)	374 (12.5)	491 (12.2)	576 (11.9)	632 (13.2)
60-80	69 (3.5)	163 (5.4)	273 (6.8)	497 (10.2)	503 (10.5)
80-100	6 (0.3)	13 (0.4)	32 (0.8)	55 (1.1)	48 (1.0)
100-150	6 (0.3)	75 (2.5)	126 (3.1)	196 (4.0)	208 (4.3)
>150	0 (0.0)	9 (0.3)	12 (0.3)	45 (0.9)	87 (1.8)
Totals	1 964 (100.0)	2 992 (100.0)	4 020 (100.0)	4 856 (100.0)	4 790 (100.0)

a. Numbers at 1 January in year shown.
na Not available

Notes
1. Figures in parentheses are percentages.
2. As absolute numbers of ships less than 10 000 dwt would have been very small (had they been available), percentage contributions have been set to zero.
3. Due to rounding percentages may not add to totals.

Source Fearnleys (1976, 1987).

The number of ships in the range 80 000 to 100 000 dwt have remained low, only 1.0 per cent in January 1987. Apparently, once it is decided to design a ship which is too large to transit the Panama Canal, it is better to exceed the Panamax limits by a large margin rather than by a small one.[1] For example, ports which have a high throughput are generally made capable of accommodating ships in excess of 100 000 dwt to benefit from economies of scale.

Overall, the average size of bulk ships has increased from 28 000 dwt in 1970 to 41 000 dwt in 1987. The trends, therefore, are of a fleet in which the ships are increasing in size. Since 1980, not only has the proportion of ships less than 18 000 dwt declined, but the absolute number of ships in this category has also declined from a peak of 763 in 1982 to 557 in 1987. It is also significant that the number of ships in the range 18 000 to 40 000 dwt also declined in 1986. However, as 1986 was the first year on record when the number of bulk ships fell, it may be premature to conclude that the fall in the number of ships in the 18 000 to 40 000 dwt range will continue. Possible future distributions of the bulk fleet are forecast in Chapter 4.

Table 2.2 and Figure I.2 show the distribution by size and age of the world bulk fleet as at January 1987. The table also illustrates the points previously made about the steady trend to larger ships and the decline in the number of ships less than 18 000 dwt. The average size of ships delivered during 1986 was 58 200 dwt compared to the average size of ships built before 1970 still on the register of 32 700 dwt. In 1986 there were 854 ships still in service which were built before 1970, representing 17.8 per cent of the fleet and 14.2 per cent of the total tonnage. In January 1987 the average age of the fleet was 9.2 years, which was a small decrease from the 9.4 years in January 1984 and 9.3 years in January 1982 (Fearnleys 1987, 13). By July 1988 the average age had increased to 9.7 years. The large number of newbuildings during the early to mid-1980s has kept the average fleet age down. However, the recent decline in new orders will, if maintained, result in a continuing increase in average age of vessels making up the world fleet. This is discussed in more detail in Chapter 4.

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1. 'Panamax' is the term applied to vessels which are considered the largest ships that can negotiate the Panama Canal; such vessels range in size from 50 000 to 80 000 dwt approximately. Other size categories in common usage are 'Handy' (25 000 to 40 000 dwt), 'Handymax' (35 000 to 50 000 dwt) and 'Cape' (100 000 to 150 000 dwt).

TABLE 2.2 DISTRIBUTION OF THE WORLD BULK FLEET: BY SIZE-AGE, JANUARY 1987

Size ('000 dwt)		Year of construction ≤1965	1966-1970	1971-1975	1976-1980	1981-85	1986
0-10	No.	na	na	na	na	na	na
	dwt	na	na	na	na	na	na
10-18	No.	56	118	157	171	46	9
	dwt	800	1 800	2 200	2 700	600	100
18-40	No.	130	357	650	732	797	89
	dwt	3 600	9 200	18 400	20 400	24 000	2 700
40-50	No.	8	60	33	65	214	43
	dwt	400	2 700	1 400	2 800	9 300	1 800
50-60	No.	5	41	71	51	36	5
	dwt	300	2 200	3 800	2 800	2 000	300
60-80	No.	6	33	100	111	229	24
	dwt	400	2 300	6 700	7 300	15 100	1 600
80-100	No.	2	18	7	10	11	0
	dwt	200	1 600	600	800	900	0
100-150	No.	0	18	78	42	62	8
	dwt	0	2 100	9 400	5 200	8 400	1 100
>150	No.	0	2	27	3	33	22
	dwt	0	300	4 800	500	6 300	4 100
Total	No.	207	647	1 123	1 185	1 428	200
	dwt	5 700	22 200	47 300	42 500	66 600	11 700

na Not available.

Source Fearnleys (1987).

DISTRIBUTION BY FLAG

The distribution of bulk ships by flag has shown considerable change over time. A feature has been the steady reduction in the fleets registered in the traditional maritime nations. The data in Table 2.3 show that the total tonnage proportion of ships registered under FOC has remained relatively constant at about 30 per cent. Figure I.3 illustrates the data shown in Table 2.3.

Figures I.4 and I.5 illustrate the distributions of deadweight tonnage and ship numbers by flag and ship size category. These distributions confirm that FOC vessels represent a reasonably constant proportion of the bulk fleet (30 to 35 per cent), but only for tonnage categories up to Panamax size. For categories above this size, OECD ships dominate with the FOC share of ships above 150 000 dwt being only 15 per cent.

A possible reason for this is that large ships are generally built for a specific, high volume trade and, as such, are likely to be registered under the flag of one of the trading partners. Furthermore, the construction of such trade-specific vessels will often be government subsidised. The preferential funding position available in these circumstances means these dedicated carriers will tend to be built larger to take full advantage of size economies, but their design may be subject to greater government influence. On the other hand, Handy-sized and Panamax ships are more attractive in the charter market being capable of more flexible operations. FOC registration saves costs and therefore, would be an advantage in the more competitive charter market. There is a growing tendency to transfer registries for the purpose of reducing total operating costs, that is, to flag out. In this way, smaller ships which cannot realise size economies, can reduce crewing, tax and registration costs to compete, while larger ships can attract economies of size and therefore need not flag out. This practice has helped to maintain FOC ship numbers and proportions in the world fleet.

Figures I.6 and I.7 illustrate the distribution of ship numbers and deadweight tonnage by flag and age. In particular, they show that for all ages less than 15 years, OECD and FOC ships represent reasonably constant proportions of the bulk fleet at approximately 35 and 30 per cent respectively. The OECD proportion is lower for ships between 15 and 20 years old but the FOC proportion increases. The FOC registries account for a much smaller proportion of ships older than 20 years than do OECD registries.

TABLE 2.3 TRENDS IN FLAG OF REGISTRATION OF BULK CARRIERS, ORE CARRIERS AND ORE-BULK-OIL CARRIERS

	1978		*1983*		*1986*	
Flag bloc	*'000 dwt*	*per cent*	*'000 dwt*	*per cent*	*'000 dwt*	*per cent*
OECD	104 393	56.6	100 058	45.4	68 657	33.8
Open registries[a]	54 144	29.3	67 701	30.7	63 291	31.1
Centrally managed economies[b]	9 582	5.2	15 286	6.9	20 144	9.9
Middle East oil exporters[c]	103	0.1	1 129	0.5	2 119	1.0
Newly industrialising countries[d]	6 265	3.4	19 880	9.0	32 544	16.0
Less developed countries[f]	8 712	4.7	13 529	6.1	12 600	6.2
Others	1 336	0.7	2 854	1.3	3 967	2.0

a. Liberia, Panama, The Bahamas, Bermuda, Cayman Is, Cyprus.
b. USSR, Bulgaria, Czechoslovakia, German Democratic Republic, Poland, Rumania, Yugoslavia, People's Republic of China, Cuba, North Korea, Vietnam.
c. Bahrain, Iran, Kuwait, Saudi Arabia, United Arab Emirates.
d. Hong Kong, Philippines, Singapore, South Korea, Taiwan.
f. Algeria, Argentina, Bangladesh, Barbados, Brazil, Chile, Columbia, Dominican Republic, Ecuador, Egypt, Guinea, India, Indonesia, Jordan, Lebanon, Malaysia, Maldive Is, Mexico, Morocco, Nauru, New Caledonia, Pakistan, Peru, St Vincent, Sri Lanka, Thailand, Tunisia, Uruguay, Vanuatu, Venezuela.

Note This table includes only the major FOC registries in the open registry classification. This is to maintain consistency in the comparison between years. While other open registries have been established during the last ten years, these new registries have only a small number of ships on their registers and this would not significantly alter the proportions shown.

Sources British Maritime Charitable Foundation (1986). Lloyd's Register of Shipping (1986). BTCE estimates.

Flag movements

While the proportion of ships sailing under open registry flags has been relatively stable, there has been considerable movement between flags. This is illustrated in Table 2.4 which summarises flag movements for six non-sequential weeks in 1986 and 1987. The table shows that, of the major FOC registries, Cyprus experienced a significant gain in tonnage, Liberia a significant loss and Panama a minor loss. Although Panama experienced only a small net change in tonnage, a large number of the flag movements involved the Panama registry. Movements into the Panama registry comprised 20 per cent of the sample and movements out comprised 21 per cent; that is, 41 per cent of the ships in the sample either moved into or out of the Panama registry.

In the sample of movements, OECD registries experienced a net loss of 1 402 000 dwt. The net movements are as follows: 985 000 dwt (70 per cent) to FOC registries, 198 000 dwt (14 per cent) to the Philippines and 220 000 dwt (16 per cent) to other flags.

The data in Table 2.4 are for six weeks only and the proportions quoted above are only approximations of the total annual flag movements. The data do suggest that there is a significant net loss of tonnage from OECD countries to other registries, especially to FOC registries and to newly industrialising countries such as the Philippines. The background to these flag movements is briefly discussed in the next section.

Open registries

Open registries, or FOC registries, are difficult to define precisely. The Rochedale Report (Bergstrand 1983), the report of a 1970 UK inquiry into shipping, identified a number of common open registry characteristics which are still being used by the International Transport Workers' Federation (ITF) in its policy of targetting FOC vessels (Fairplay 1987). These characteristics are as follows:

- The country of registry allows ownership and/or control of its merchant vessels by non-citizens.
- Access to the registry is easy.
- Taxes on the income from the ships are not levied locally or are low.
- The country of registry is a small power with no national requirements under any foreseeable circumstances for all the shipping registered, but receipts from very small charges on a large tonnage may produce a substantial effect on its national income and balance of payments.
- Crewing of ships by non-nationals is freely permitted.
- The country of registry has neither the power nor the administrative machinery to impose effectively any government or international regulations; neither has the country the wish nor the power to control the companies themselves (Bergstrand 1983, 1-2).

TABLE 2.4 FLAG MOVEMENTS FOR 6 NON-SEQUENTIAL WEEKS IN 1986 AND 1987 FOR BULK CARRIERS

('000 dwt)

	To											
From	*Liberia*	*Panama*	*Cyprus*	*Other FOC*	*Britain*	*Norway*	*Japan*	*Greece*	*Other OECD*	*Philip-pines*	*Others*	*Total*
Liberia	..	172.6	213.4	0	168.5	0	0	103.1	60.9	215.6	101.1	1 035.1
Panama	37.7	..	302.7	16.4	92.8	0	21.3	33.7	0	255.8	327.9	1 088.3
Cyprus		0	..	0	0	0	0	0	0	0	53.8	53.8
Other FOC	40.9	0	0	0	0	0	0	40.9	54.2	0	26.3	162.3
Britain	0	69.6	27.5	0	..	0	0	190.4	64.2	0	23.7	375.4
Norway	0	205.6	0	120.6	0	..	0	0	0	0	0	326.3
Japan	0	269.1	94.8	64.8	38.1	0	..	0	0	129.5	0	596.3
Greece	111.6	0	192.1	108.6	76.6	0	0	..	0	120.5	121.9	731.4
Other OECD	37.6	52.5	0	205.4	168.5	0	0	38.4	0	0	74.1	576.6
Philippines	0	170.2	0	0	0	0	0	52.1	0	..	0	222.2
Others	19.1	123.1	210.7	0	0	0	0	0	0	0	19.2	372.1
Total	246.9	1 062.6	1 041.2	515.9	544.5	0	21.3	458.5	179.3	721.4	748.0	5 539.6

.. Not applicable.

Note Due to rounding figures may not add to totals.

Source Lloyd's Shipping Index (1986, 1987).

The major open registries are located in Liberia, Panama, Cyprus, The Bahamas and Bermuda. More recently, some countries, such as Vanuatu, have provided open registry facilities. Some of the traditional maritime countries have responded to the movement of ships away from their flags by opening registries with some of the characteristics of an open registry. These include the Isle of Man (UK) and the Kerguelen Islands (France). A Norwegian International Shipping Registry (NIS) opened recently. These registries have been referred to as captive open registries (Kappel 1987).

Not all open registries exhibit all of the characteristics indicated above. Table 2.5 illustrates the main requirements of registration for selected flags. At the time of writing, it was not known what the final requirements for registration with the NIS would be. However, the key elements of the Norwegian government's proposals were (Clark 1987):

- no nationality requirements on crewing;
- vessels on the registry will be able to avail themselves of Norway's flexible crewing regulations;
- no nationality requirements on equity capital;
- vessels entered into the registry must formally be owned by entities incorporated in Norway;
- a significant part of the operating functions should be carried out from Norway;
- foreign owners will be granted partial exemption from Norwegian taxation; and
- foreign seamen will be exempt from Norwegian income tax.

The movement of bulk ships between flags has much to do with conditions in the bulk shipping market. A diminishing number of dry bulk shipowners operate in a spot market which has many of the important characteristics of what economists refer to as a perfect market. The Lloyd's Shipping Economist (1987c) listed the following as the main characteristics of the bulk shipping spot market:

- A large number of operators exists with no single operator or group of operators being large enough to dominate or even influence significantly the mainstream dry bulk trades.
- Demand for shipping capacity is derived from world-wide trade in basic commodities, principally iron ore, coal (thermal and metallurgical) and grains.
- Rates are determined in a free, constantly changing market.

TABLE 2.5 MAIN REQUIREMENTS ON REGISTRATION FOR SELECTED FLAGS

Flag	*Vessel age restrictions*	*Dual or parallel registration*	*Nationality restrictions and requirements*		
			Ownership	*Management*	*Crewing*
Isle of Man (IoM)	None	No	British/Commonwealth citizen resident on IoM or IoM incorporated company	IoM based	UK, Eire or Commonwealth certificates
Cyprus	<17 (older vessels subject to stricter management/ownership requirements)	Permitted by bareboat charter	At least 50 per cent by Cypriots or by local registered company	None	Minimum of 15 per cent must be Cypriots if available
Malta	None	No	Maltese citizens or body corporate	None	None
Liberia	<20 (also <25 subject to limited exceptions)	Permitted	Liberian citizen or corporation	None	None
Vanuatu	<20 (may be waived in exceptional cases)	Permitted by bareboat charter	Citizens or Vanuatu corporation	None	None
The Bahamas	<12 (older vessels with ministerial permission on certain conditions)	Permitted by bareboat charter	Foreign ownership permitted	None	None

TABLE 2.5 (Cont.) MAIN REQUIREMENTS ON REGISTRATION FOR SELECTED FLAGS

Flag	*Vessel age restrictions*	*Dual or parallel registration*	*Nationality restrictions and requirements*		
			Ownership	*Management*	*Crewing*
Bermuda	None	No	British subjects or bodies corporate established under HM Dominion laws	None	Certificates of UK or certain Commonwealth countries
St Vincent	<40	Permitted	None, but must have registered local agent	None	None

Source Lloyd's Shipping Economist (1987b)

- Information about rates and the availability of ships is quite well known and publicised.
- Information about mainstream trade patterns is quite readily available.
- There is no great variation in operating costs between shipowners (except, admittedly, between Filipino and American crewed vessels).
- There are reasonably low barriers to entry for potential shipowners.

However, the spot market is only a small part of the whole. The market conduct of the remaining bulk shipping industry is becoming increasingly imperfect. Some of the reasons for this trend are as follows:

- The supply of ships to the overall market is becoming more distorted through direct and indirect government subsidisation of newbuildings; through back-to-back agreements between shipbuilders and shipowners with respect to long-term bulk shipping contracts; through the existence of State-owned and subsidised operators in some centrally managed economies, and so on.
- While companies may leave the industry, the ships owned by them generally do not. Capacity is only reduced through scrapping.
- More and more bulk cargo is being reserved for particular bulk ships and shipowners through government and industry policy action.
- Freight rate rigidities are being built into long-term contracts, for example, by back-to-back shipyard and shipowner agreements referred to previously. The extent to which these fixed freight rates differ from prevailing spot rates is a measure of the market imperfection caused by back-to-back agreements.

These factors have distorted the overall relationship between demand and supply and have helped to ensure that the supply of ships to the market has exceeded the demand for them. Oversupply is discussed further in Chapters 4 and 8. The surplus of bulk shipping capacity has been endemic for several years. Shipowners have responded by attempting to reduce costs. There are only limited opportunities available to them to achieve this objective. One way is to reduce crewing levels; in Australia this usually means the acquisition of a new ship. This is discussed further in Chapter 6. The other way is to transfer an existing ship to a flag which permits the employment of low cost crews. This is perhaps the most important reason for the current movement of shipping from Western European registries to open registries and registries which allow low cost crews. Lower taxation and registration fees are also important considerations in the decision to change flags. While market conditions remained depressed, the attraction for shipowners to switch flags from the traditional maritime countries to ones offering lower costs was maintained.

SUMMARY

The size of the bulk fleet has increased substantially since 1970, growing from 55 million dwt in 1970 to 196 million dwt in 1987. During this time, there has been a major increase in the number of ships larger than 100 000 dwt and a reduction in the number of ships smaller than 18 000 dwt. The proportion of Panamax ships (60 000 dwt to 80 000 dwt) in the fleet has also had a major increase trebling over the period 1970 to 1987. As a result the average size of bulk ships has increased from 28 000 dwt in 1970 to 41 000 dwt in 1987.

Overall, the proportion of ships registered in OECD countries has declined over the last decade while the proportion of ships registered in newly industrialising countries has increased. The proportion of ships registered in open registries has remained reasonably constant at around 30 per cent. However, for ships over 150 000 dwt the proportion has declined to 15 per cent. OECD-registered ships dominate this segment of the market.

The average age of bulk ships is 9.2 years and has not changed much in the last five years.

CHAPTER 3 DISTRIBUTIONS OF THE VISITING FLEET

In Chapter 2 the distribution of the world bulk fleet was analysed by size, age and flag of vessel. Analysis was also made of trends in these distributions. This chapter is devoted to a sub-set of the world bulk fleet, in particular those ships which visited Australia in 1985-86. An examination by size, age and flag is similarly made and compared with the corresponding distributions of the world fleet. However, the analysis is extended, in this chapter, to an examination of those bulk ships which carry Australian grain exports to overseas markets.

During 1985-86 approximately 1470 bulk, ore and ore-bulk-oil (obo) carriers made over 5800 calls to Australian ports. On average, each bulk vessel made almost four calls somewhere on the Australian coast during that year.

Table 3.1 sets out the distribution of bulk ship movements to and from Australian ports during 1985-86, the proportions shown being derived by summarising the movements of ships stored in the database generated for this study.[1] In descriptive terms, this table shows that during 1985-86:

- almost half (44.9 per cent) of bulk shipping port calls were single port-of-call movements;
- almost three-quarters (72 per cent) of single port-of-call movements were made via the same inward and outward shipping channels;
- inward and outward movements via the direct trade route between Australia and Japan accounted for more than 50 per cent of single port-of-call movements; and

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1. The database was derived from Lloyd's Register of Ships and an extract from Department of Transport and Communications' Sea Transport Information System.

TABLE 3.1 BULK SHIP MOVEMENTS TO AND FROM AUSTRALIAN PORTS, 1985-86
(per cent)

Movement	*Proportion*
Foreign port to a single Australian port to Foreign port	
Same shipping channel, inward and outward	
Japan to Australia to Japan	16.5
Other country to Australia to other country	15.8
Different shipping channels, inward and outward	
Japan to Australia to other country	4.7
Other country to Australia to Japan	1.8
Other country to Australia to other country	6.1
Other	55.1
Total	100.0

Source BTCE estimates.

- 'Other' movements amounted to 55.1 per cent of the total, being foreign and Australian ships involved in international trade as well as Australian ships in Australian coastal trade (the proportions of which cannot be distinguished).

OVERALL STATISTICAL MEASURES

Further analysis of the database developed for this study yielded some overall statistical measures of the world and visiting bulk fleets. In particular, Tables II.1 to II.4 contain statistical data which detail comparisons between various characteristics of those bulk, ore and obo carriers which made, or did not make, at least one call to an Australian port during 1985-86. The bulk ship characteristics compared are:

- FOC and non-FOC distributions;
- age and deadweight tonnage statistics;
- power, speed and fuel consumption statistics; and
- length, breadth and draught statistics.

From the comparisons the following can be concluded:

- As at mid-1986, 4849 vessels constituted the world dry bulk shipping fleet and this fleet was dominated by 4427 bulk carriers (91.3 per cent of the total number of vessels).

- Approximately one-third of the total fleet and the bulk carrier fleet was registered in open registries, although the proportions for obo and ore carriers were substantially different being 41 per cent and 19 per cent respectively.
- Those bulk and ore carriers which visited Australian ports during 1985-86 were substantially newer ships than those which did not visit. However, the obo carriers which made at least one call were about one year older than their non-calling counterparts.
- The average capacity of visiting bulk vessels was significantly greater than that of non-visitors. Compared with ships which did not make calls, visiting bulk carriers were 51 per cent larger overall, obo carriers were 24 per cent larger and ore carriers were almost four times as large. All of these comparative statistics reflect both Australia's specific and lengthy trading patterns as well as the greater scale economies planned for and being achieved by the generally larger and newer bulk ships involved in those trades.
- Being larger ships, the engine maximum power ratings, on average, were correspondingly larger for ships which visited Australian ports. The fuel consumption rates were also greater for ships which visited during 1985-86, but this result is a reflection of a comparatively larger ship size outweighing the fuel savings to be made with newer fuel efficient engines.
- For similar reasons, average length, breadth and draught of the visiting ships were all greater than for those that did not come to Australia during 1985-86.

DISTRIBUTIONS BY SIZE

The simplest way to analyse the size distribution of the 1985-86 bulk fleet which called at Australian ports and to make comparisons with the corresponding world fleet distribution, involves the division of the data into broad deadweight tonnage categories.[2]

Data for bulk ships visiting Australian ports can be compiled either on the basis of the total number of port calls per annum or the total

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1. The broad deadweight tonnage categories were deliberately chosen to align themselves with commonly accepted bulk ship size classifications, that is, Handy, Handymax, Panamax and Cape size. Allowing for the overlapping of the Handy and Handymax definitions, the size categories selected were 0 to 19 999, 20 000 to 29 999, 30 000 to 39 999, 40 000 to 49 999, 50 000 to 79 999, 80 000 to 99 999, 100 000 to 149 999 and $\geq$150 000 dwt.

number of ships engaged in trade per annum. To distinguish between the two data sets, the former is referred to as the 'port calls fleet' and the later as the 'visitors fleet'. The sample used in this study consisted of 5810 port calls, made by 1467 individual bulk ship visitors. Whereas the world bulk shipping fleet is a measure of the bulk shipping stock at 30 June 1986, both the port calls and visitors fleets constitute bulk shipping flows over the year 1985-86. Some other measurement period, other than a year, may have been chosen; such a period is reasonable, however, as a basis over which to measure the short-term bulk shipping demand placed on Australian ports. On the other hand, it is a sufficiently long period to account for any seasonal variations in bulk shipping flows (for example, with grain shipments) and to permit the accumulation of sufficient data from which to draw statistical inferences.

Set out in Tables 3.2 to 3.5 are four distributions which show the total deadweight tonnage of, and the ship numbers in, the 1985-86 total port calls and visitors fleets.

From these tabular and graphical sources, the following major conclusions can be drawn:

- A great proportion of the total tonnage of the visitors and port calls fleets was concentrated in the larger ships - in particular the Panamax- and Cape-sized vessels. On the other hand, the ship numbers of the visitors and port calls fleets were concentrated at the smaller Handy-sized end of the spectrum. This result stems from the fact that, although they were relatively few in number, the visiting bulk ships at the larger end of the size spectrum were disproportionately large, meaning their aggregate tonnage was relatively greater than that of the visiting bulk ships at the smaller end of the spectrum.
- FOC carriers were represented much more in the lower tonnage categories (less than 50 000 dwt) than in the upper range.
- OECD vessels were represented over the entire spectrum but dominated the vessels greater than 100 000 dwt.

TABLE 3.2 TOTAL DEADWEIGHT TONNAGE OF THE 1985-86 BULK SHIPPING TOTAL PORT CALLS FLEET BY FLAG BY VESSEL SIZE

('000 dwt)

	Vessel size								
Flag bloc	*0-20*	*20-30*	*30-40*	*40-50*	*50-80*	*80-100*	*100-150*	*≥150*	*Total*
OECD	4 805	17 277	10 182	9 370	33 728	6 640	64 205	27 466	173 673
	(1.55)	(5.56)	(3.28)	(3.02)	(10.86)	(2.14)	(20.67)	(8.84)	(55.92)
Open registries	4 637	8 207	8 192	4 475	5 965	242	4 721	2 117	38 556
	(1.49)	(2.64)	(2.64)	(1.44)	(1.92)	(0.08)	(1.52)	(0.68)	(12.41)
Centrally managed	787	3 416	3 780	2 023	5 176	0	1 526	0	16 708
economies	(0.25)	(1.10)	(1.22)	(0.65)	(1.67)	(0.00)	(0.49)	(0.00)	(5.38)
Middle East oil	0	135	866	774	0	0	0	0	1 775
exporters	(0.00)	(0.04)	(0.28)	(0.25)	(0.00)	(0.00)	(0.00)	(0.00)	(0.57)
Newly industrialising	2 789	5 761	11 673	4 041	17 988	1 256	21 293	7 818	72 619
countries	(0.90)	(1.86)	(3.76)	(1.30)	(5.79)	(0.40)	(6.86)	(2.52)	(23.38)
Less developed	65	1 363	1 893	1 476	1 929	0	0	0	6 726
countries	(0.02)	(0.44)	(0.61)	(0.48)	(0.62)	(0.00)	(0.00)	(0.00)	(2.17)
Others	0	170	0	88	246	0	0	0	504
	(0.00)	(0.05)	(0.00)	(0.03)	(0.08)	(0.00)	(0.00)	(0.00)	(0.16)
Total	13 083	36 329	36 586	22 247	65 032	8 138	91 745	37 401	310 561
	(4.21)	(11.70)	(11.78)	(7.16)	(20.94)	(2.62)	(29.54)	(12.04)	(100.00)

Notes 1. Figures in parentheses are percentages of grand total.
2. The blocs of countries constituting the main flag categories, except OECD, are set out in Table 2.3.

Sources Lloyd's Register of Shipping (1986). BTCE estimates.

TABLE 3.3 SHIP NUMBERS IN THE 1985-86 BULK SHIPPING TOTAL PORT CALLS FLEET BY FLAG BY VESSEL SIZE

	Vessel size ('000 dwt)								
Flag bloc	*0-20*	*20-30*	*30-40*	*40-50*	*50-80*	*80-100*	*100-150*	*≥150*	*Total*
OECD	288	701	296	213	493	76	516	149	2 732
	(4.96)	(12.07)	(5.09)	(3.67)	(8.49)	(1.31)	(8.88)	(2.56)	(47.02)
Open registries	274	327	231	106	96	3	39	12	1 088
	(4.72)	(5.63)	(3.98)	(1.82)	(1.65)	(0.05)	(0.67)	(0.21)	(18.73)
Centrally managed	46	135	107	47	77	0	11	0	423
economies	(0.79)	(2.32)	(1.84)	(0.81)	(1.33)	(0.00)	(0.19)	(0.00)	(7.28)
Middle East oil	0	5	25	18	0	0	0	0	48
exporters	(0.00)	(0.09)	(0.43)	(0.31)	(0.00)	(0.00)	(0.00)	(0.00)	(0.83)
Newly industrialising	169	216	330	91	288	14	172	49	1 329
countries	(2.91)	(3.72)	(5.68)	(1.57)	(4.96)	(0.24)	(2.96)	(0.84)	(22.87)
Less developed	4	55	55	35	28	0	0	0	177
countries	(0.07)	(0.95)	(0.95)	(0.60)	(0.48)	(0.00)	(0.00)	(0.00)	(3.05)
Others	0	7	0	2	4	0	0	0	13
	(0.00)	(0.12)	(0.00)	(0.03)	(0.07)	(0.00)	(0.00)	(0.00)	(0.22)
Total	781	1 446	1 044	512	986	93	738	210	5 810
	(13.44)	(24.89)	(17.97)	(8.81)	(16.97)	(1.60)	(12.70)	(3.61)	(100.00)

Notes 1. Figures in parentheses are percentages of grand total.
2. The blocs of countries constituting the main flag categories, except OECD, are set out in Table 2.3.

Sources Lloyd's Register of Shipping (1986). BTCE estimates.

TABLE 3.4 TOTAL DEADWEIGHT TONNAGE OF THE 1985-86 BULK SHIPPING VISITORS FLEET BY FLAG BY VESSEL SIZE
('000 dwt)

	Vessel size								
Flag bloc	*0-20*	*20-30*	*30-40*	*40-50*	*50-80*	*80-100*	*100-150*	*≥150*	*Total*
OECD	361	2 631	2 906	1 628	6 987	1 131	11 336	6 827	33 807
	(0.45)	(3.31)	(3.65)	(2.05)	(8.78)	(1.42)	(14.25)	(8.58)	(42.49)
Open registries	893	3 141	3 853	2 168	3 369	81	2 430	711	16 646
	(1.12)	(3.95)	(4.84)	(2.72)	(4.23)	(0.10)	(3.05)	(0.89)	(20.92)
Centrally managed	325	1 122	1 378	737	1 196	0	259	0	5 017
economies	(0.41)	(1.41)	(1.73)	(0.93)	(1.50)	(0.00)	(0.33)	(0.00)	(6.31)
Middle East oil	0	27	553	558	0	0	0	0	1 138
exporters	(0.00)	(0.03)	(0.69)	(0.70)	(0.00)	(0.00)	(0.00)	(0.00)	(1.43)
Newly industrialising	536	1 218	2 419	963	5 556	352	6 189	3 570	20 803
countries	(0.67)	(1.53)	(3.04)	(1.21)	(6.98)	(0.44)	(7.78)	(4.49)	(26.14)
Less developed	16	356	566	423	568	0	0	0	1 929
countries	(0.02)	(0.45)	(0.71)	(0.53)	(0.71)	(0.00)	(0.00)	(0.00)	(2.42)
Others	0	125	0	44	62	0	0	0	231
	(0.00)	(0.16)	(0.00)	(0.06)	(0.08)	(0.00)	(0.00)	(0.00)	(0.29)
Total	2 131	8 620	11 675	6 521	17 738	1 564	20 214	11 108	79 571
	(2.68)	(10.83)	(14.67)	(8.20)	(22.29)	(1.97)	(25.40)	(13.96)	(100.00)

Notes 1. Figures in parentheses are percentages of grand total.
2. The blocs of countries constituting the main flag categories, except OECD, are set out in Table 2.3.

Sources Lloyd's Register of Shipping (1986). BTCE estimates.

TABLE 3.5 SHIP NUMBERS IN THE 1985-86 BULK SHIPPING VISITORS FLEET BY FLAG BY VESSEL SIZE

	Vessel size ('000 dwt)								
Flag bloc	*0-20*	*20-30*	*30-40*	*40-50*	*50-80*	*80-100*	*100-150*	*≥150*	*Total*
OECD	21	104	82	38	107	13	90	38	493
	(1.43)	(7.09)	(5.59)	(2.59)	(7.29)	(0.89)	(6.13)	(2.59)	(33.61)
Open registries	52	124	108	51	54	1	20	4	414
	(3.54)	(8.45)	(7.36)	(3.48)	(3.68)	(0.07)	(1.36)	(0.27)	(28.22)
Centrally managed	20	44	39	17	19	0	2	0	141
economies	(1.36)	(3.00)	(2.66)	(1.16)	(1.30)	(0.00)	(0.14)	(0.00)	(9.61)
Middle East oil	0	1	16	13	0	0	0	0	30
exporters	(0.00)	(0.07)	(1.09)	(0.89)	(0.00)	(0.00)	(0.00)	(0.00)	(2.04)
Newly industrialising	31	47	68	22	89	4	50	22	333
countries	(2.11)	(3.20)	(4.64)	(1.50)	(6.07)	(0.27)	(3.41)	(1.50)	(22.70)
Less developed	1	14	16	10	8	0	0	0	49
countries	(0.07)	(0.95)	(1.09)	(0.68)	(0.55)	(0.00)	(0.00)	(0.00)	(3.34)
Others	0	5	0	1	1	0	0	0	7
	(0.00)	(0.34)	(0.00)	(0.07)	(0.07)	(0.00)	(0.00)	(0.00)	(0.48)
Total	125	339	329	152	278	18	162	64	1 467
	(8.52)	(23.11)	(22.43)	(10.36)	(18.95)	(1.23)	(11.04)	(4.36)	(100.00)

Notes 1. Figures in parentheses are percentages of grand total.
2. The blocs of countries constituting the main flag categories, except OECD, are set out in Table 2.3.

Sources Lloyd's Register of Shipping (1986). BTCE estimates.

Comparisons with the world fleet

The world fleet analysed in Chapter 2 differs in some important aspects from the world fleet analysed in this chapter.[3] Nevertheless, the differences are not great - the conclusions drawn in Chapter 2 and in this chapter are not inconsistent.

If the tables and graphs setting out the distributions of the visitors and port calls fleets are compared with the corresponding world fleet tables set out in Tables 3.6 and 3.7 and world fleet graphs set out in Appendix I, it will be observed that:

- the world fleet's total deadweight tonnage and numbers distributions were both skewed towards the smaller ship sizes, that is, to the left of the graphical distributions; and
- the extent to which the world fleet was distributed to the left was greater than the extent to which the visitors and port calls fleets were distributed towards the smaller ship sizes.

To facilitate the comparisons between the ship numbers and total tonnage distributions, Figures 3.1 and 3.2 have been prepared using the total percentages shown at the base of each column in Tables 3.2 to 3.7, that is, the aggregate percentage distributions of ship numbers and deadweight tonnage for each category of ship size. These two figures show the differences between the three distributions. In particular, the relative weighting of the visitors and port calls tonnage distributions towards the much larger bulk ships (Cape-sized and above) and the relative weighting of the world fleet's ship numbers distribution towards the smaller vessels (less than 30 000 dwt) are evident. In other words, the vessels visiting Australia were, on average, larger than that which the world fleet would suggest. Moreover, the application of standard Chi-square tests to the data demonstrates statistically that the world fleet distributions are significantly different (with only one exception at the 5 per cent level of significance) from those of the port calls and visitors fleets with respect to ship numbers and total deadweight tonnage. The results of these Chi-square tests are set out in Appendix III.

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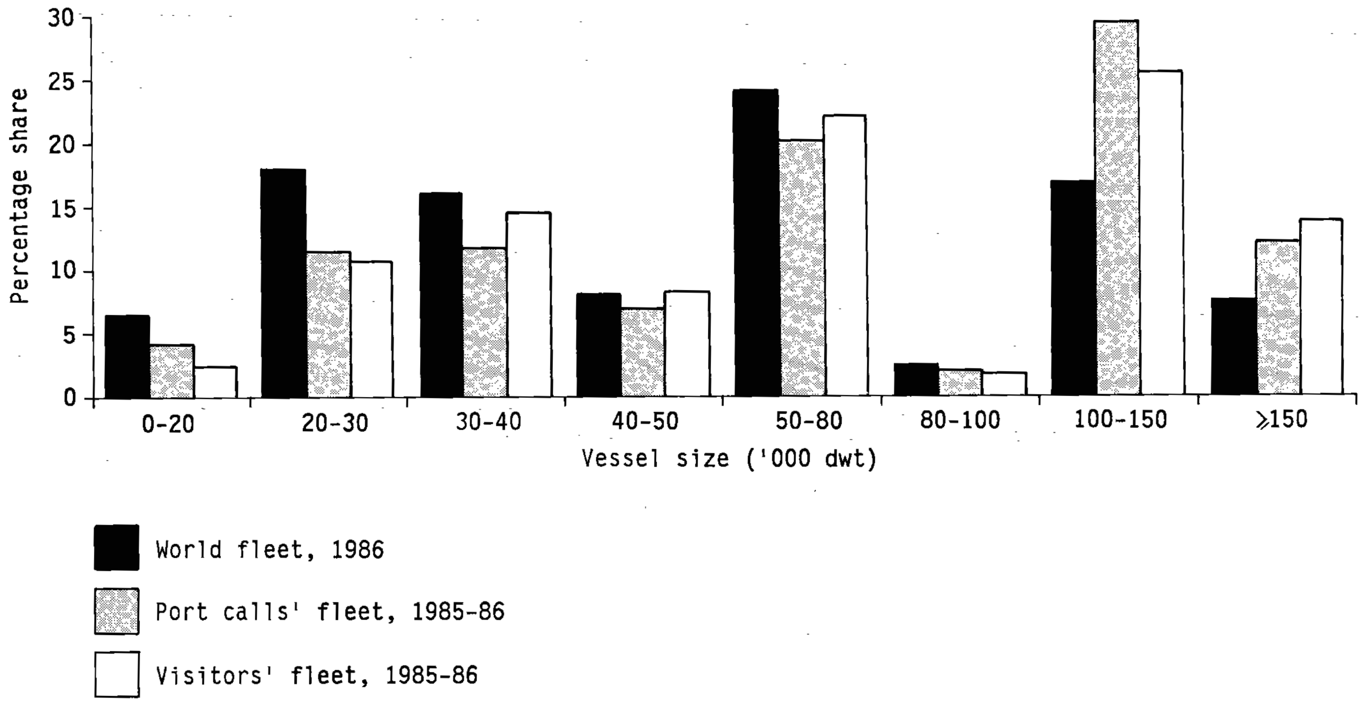
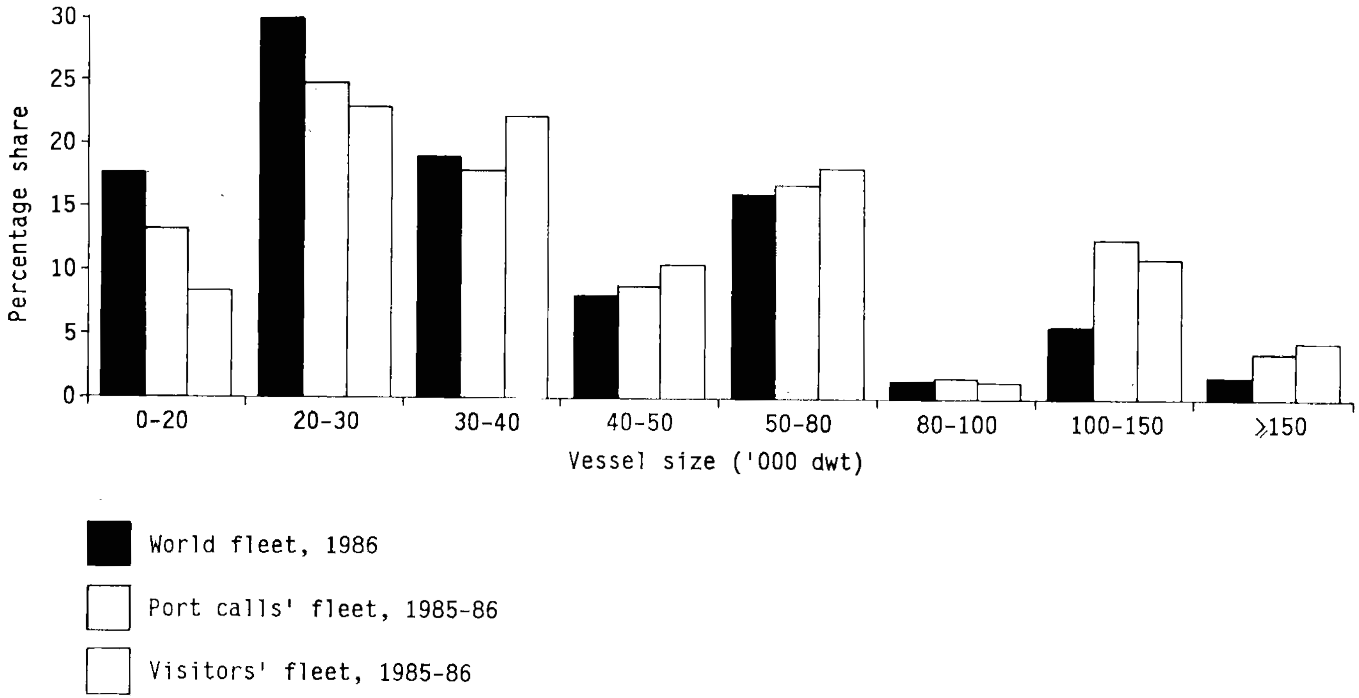
3. The world fleet of Chapter 2 was composed of dry bulk carriers, ore carriers and some specialty carriers such as bulk-car and bulk-container carriers. However, it did not include obo carriers nor did it include vessels under 10 000 dwt (Fearnleys 1987). In this chapter the world and the visiting bulk fleets consist of all bulk, ore and obo carriers. This means the world fleet distributions of total tonnage and ship numbers by vessel size, as set out in Tables 3.6 and 3.7, differ from those specified in Chapter 2, especially with respect to the larger ships amongst which the obo carriers are distributed.



Source BTCE estimates.

Figure 3.1 Comparison of bulk ship deadweight tonnage distributions by vessel size



Source BTCE estimates.

Figure 3.2 Comparison of bulk ship numbers' distributions by vessel size

TABLE 3.6 TOTAL DEADWEIGHT TONNAGE OF THE WORLD BULK SHIPPING FLEET BY FLAG, BY VESSEL SIZE, JUNE 1986
('000 dwt)

	Vessel size								
Flag bloc	*0-20*	*20-30*	*30-40*	*40-50*	*50-80*	*80-100*	*100-150*	*≥150*	*Total*
OECD	2 817	10 867	8 489	4 726	15 061	2 932	15 975	7 790	68 657
	(1.39)	(5.34)	(4.18)	(2.32)	(7.41)	(1.44)	(7.86)	(3.83)	(33.77)
Open registries	4 370	13 781	11 053	5 963	16 671	1 565	7 629	2 261	63 293
	(2.15)	(6.78)	(5.44)	(2.93)	(8.20)	(0.77)	(3.75)	(1.11)	(31.13)
Centrally managed	3 078	4 746	4 730	1 315	4 780	175	1 320	0	20 144
economies	(1.51)	(2.33)	(2.33)	(0.65)	(2.35)	(0.09)	(0.65)	(0.00)	(9.91)
Middle East oil	165	78	799	1 026	52	0	0	0	2 120
exporters	(0.08)	(0.04)	(0.39)	(0.50)	(0.03)	(0.00)	(0.00)	(0.00)	(1.04)
Newly industrialising	1 257	3 496	4 581	2 079	8 556	694	7 575	4 305	32 543
countries	(0.62)	(1.72)	(2.25)	(1.02)	(4.21)	(0.34)	(3.73)	(2.12)	(16.01)
Less developed	1 016	2 803	2 519	1 556	3 133	185	1 387	0	12 599
countries	(0.50)	(1.38)	(1.24)	(0.77)	(1.54)	(0.09)	(0.68)	(0.00)	(6.20)
Others	532	916	367	255	1 111	87	531	167	3 966
	(0.26)	(0.45)	(0.18)	(0.13)	(0.55)	(0.04)	(0.26)	(0.08)	(1.95)
Total	13 235	36 687	32 538	16 920	49 364	5 638	34 417	14 523	203 322
	(6.51)	(18.04)	(16.00)	(8.32)	(24.28)	(2.77)	(16.93)	(7.14)	(100.00)

Notes 1. Figures in parentheses are percentages of grand total.
2. The blocs of countries constituting the main flag categories, except OECD, are set out in Table 2.3.

Sources Lloyd's Register of Shipping (1986). BTCE estimates.

TABLE 3.7 SHIP NUMBERS IN THE WORLD BULK SHIPPING FLEET BY FLAG, BY VESSEL SIZE, JUNE 1986

	Vessel size ('000 dwt)								
Flag bloc	*0-20*	*20-30*	*30-40*	*40-50*	*50-80*	*80-100*	*100-150*	*≥150*	*Total*
OECD	200	433	243	107	234	34	128	44	1 423
	(4.13)	(8.94)	(5.02)	(2.21)	(4.83)	(0.70)	(2.64)	(0.91)	(29.39)
Open registries	266	543	313	137	263	18	65	13	1 618
	(5.49)	(11.21)	(6.46)	(2.83)	(5.43)	(0.37)	(1.34)	(0.27)	(33.42)
Centrally managed	211	190	135	30	80	2	12	0	660
economies	(4.36)	(3.92)	(2.79)	(0.62)	(1.65)	(0.04)	(0.25)	(0.00)	(13.63)
Middle East oil	9	3	23	24	1	0	0	0	60
exporters	(0.19)	(0.06)	(0.48)	(0.50)	(0.02)	(0.00)	(0.00)	(0.00)	(1.24)
Newly industrialising	80	135	128	48	136	8	61	26	622
countries	(1.65)	(2.79)	(2.64)	(0.99)	(2.81)	(0.17)	(1.26)	(0.54)	(12.85)
Less developed	72	109	69	36	49	2	12	0	349
countries	(1.49)	(2.25)	(1.43)	(0.74)	(1.01)	(0.04)	(0.25)	(0.00)	(7.21)
Others	32	36	11	6	18	1	5	1	110
	(0.66)	(0.74)	(0.23)	(0.12)	(0.37)	(0.02)	(0.10)	(0.02)	(2.27)
Total	870	1 449	922	388	781	65	283	84	4 842
	(17.97)	(29.93)	(19.04)	(8.01)	(16.13)	(1.34)	(5.84)	(1.73)	(100.00)

Notes 1. Figures in parentheses are percentages of grand total.
2. The blocs of countries constituting the main flag categories, except OECD, are set out in Table 2.3.

Sources Lloyd's Register of Shipping (1986). BTCE estimates.

DISTRIBUTIONS BY AGE

Tables 3.8 to 3.11 set out the distributions of the 1985-86 total port calls and visitors fleets by age of vessel and by flag.[4] In analogous fashion to the ship size distributions described previously, the age distributions are defined in terms of numbers of ships and in total deadweight tonnage for each category of age and flag. Percentage shares which each age and flag category represents in terms of the entire fleet are also given in the four tables.

The tables reveal the following characteristics of the visiting fleet:

- The newest bulk ships (of ages up to 5.5 years) dominated both the visitors and port calls fleets, in terms of ship numbers and total deadweight tonnage. In fact, over half of the total deadweight tonnage and over 45 per cent of the ship numbers were represented by this newest category of visiting bulk ships.
- After the dominant proportions achieved by the newest ships, a generally steady decline in total tonnage and ship numbers was represented by the four older ship categories (of ages greater than 5.5 years).
- OECD and FOC vessels are concentrated at the newer end of the age spectrum, whereas vessels of the newly industrialising flags tend to be older on average.
- Vessels of the centrally managed economies are represented at all ages but dominate the oldest end of the spectrum.

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4. Ages of vessels are defined at June 1986 and are grouped in the following categories:
   - 0.0 to 5.5 years, corresponding to years of construction 1981, ..., 1986 (noting that the data base does not extend beyond mid-1986 which means ships constructed during 1986 cannot be older than 0.5 years during the analysis period);
   - 5.5 to 10.5 years, corresponding to years of construction 1976, ..., 1980;
   - 10.5 to 15.5 years, corresponding to years of construction 1971, ..., 1975;
   - 15.5 to 20.5 years, corresponding to years of construction 1966, ..., 1970; and
   - 20.5 years and older, corresponding to years of construction before 1966.

TABLE 3.8 TOTAL DEADWEIGHT TONNAGE OF THE 1985-86 BULK SHIPPING TOTAL PORT CALLS FLEET BY FLAG BY AGE
('000 dwt)

	Age (years)					
Flag bloc	*0.0-5.5*	*5.5-10.5*	*10.5-15.5*	*15.5-20.5*	*> 20.5*	*Total*
OECD	98 940	40 757	25 725	8 223	0	173 645
	(31.88)	(13.13)	(8.29)	(2.65)	(0.00)	(55.95)
Open registries	21 016	10 208	5 250	1 888	91	38 453
	(6.77)	(3.29)	(1.69)	(0.61)	(0.03)	(12.39)
Centrally managed economies	2 226	2 233	3 952	4 968	3 329	16 708
	(0.72)	(0.72)	(1.27)	(1.60)	(1.07)	(5.38)
Middle East oil exporters	933	539	303	0	0	1 775
	(0.30)	(0.17)	(0.10)	(0.00)	(0.00)	(0.57)
Newly industrialising	36 095	9 668	18 107	8 242	409	75 521
countries	(11.63)	(3.12)	(5.83)	(2.66)	(0.13)	(23.37)
Less developed countries	3 775	1 631	1 207	0	113	6 726
	(1.22)	(0.53)	(0.39)	(0.00)	(0.04)	(2.17)
Others	0	115	316	73	0	504
	(0.00)	(0.04)	(0.10)	(0.02)	(0.00)	(0.16)
Total	162 985	65 151	54 860	23 394	3 942	310 332
	(52.52)	(20.99)	(17.68)	(7.54)	(1.27)	(100.00)

Notes 1. Figures in parentheses are percentages of grand total.
2. The blocs of countries constituting the main flag categories, except OECD, are set out in Table 2.3.

Sources Lloyd's Register of Shipping (1986). BTCE estimates.

TABLE 3.9 SHIP NUMBERS IN THE 1985-86 BULK SHIPPING TOTAL PORT CALLS FLEET BY FLAG BY AGE

	Age (years)					
Flag bloc	*0.0-5.5*	*5.5-10.5*	*10.5-15.5*	*15.5-20.5*	*> 20.5*	*Total*
OECD	1 296	923	404	108	0	2 731
	(22.34)	(15.91)	(6.96)	(1.86)	(0.00)	(47.07)
Open registries	587	362	93	39	3	1 084
	(10.12)	(6.24)	(1.60)	(0.67)	(0.05)	(18.68)
Centrally managed economies	62	67	73	119	102	423
	(1.07)	(1.15)	(1.26)	(2.05)	(1.76)	(7.29)
Middle East oil exporters	23	15	10	0	0	48
	(0.40)	(0.26)	(0.17)	(0.00)	(0.00)	(0.83)
Newly industrialising	592	312	290	122	10	1 326
countries	(10.20)	(5.38)	(5.00)	(2.10)	(0.17)	(22.85)
Less developed countries	88	48	38	0	3	177
	(1.52)	(0.83)	(0.65)	(0.00)	(0.05)	(3.05)
Others	0	3	7	3	0	13
	(0.00)	(0.05)	(0.12)	(0.05)	(0.00)	(0.22)
Total	2 648	1 730	915	391	118	5 802
	(45.64)	(29.82)	(15.77)	(6.74)	(2.03)	(100.00)

Notes 1. Figures in parentheses are percentages of grand total.
2. The blocs of countries constituting the main flag categories, except OECD, are set out in Table 2.3.

Sources Lloyd's Register of Shipping (1986). BTCE estimates.

TABLE 3.10 TOTAL DEADWEIGHT TONNAGE OF THE 1985-86 BULK SHIPPING VISITORS FLEET BY FLAG BY AGE
('000 dwt)

	Age (years)					
Flag bloc	*0.0-5.5*	*5.5-10.5*	*10.5-15.5*	*15.5-20.5*	*> 20.5*	*Total*
OECD	18 782	6 494	7 090	1 413	0	33 779
	(23.63)	(8.17)	(9.92)	(1.78)	(0.00)	(42.50)
Open registries	9 125	4 185	2 562	680	68	16 620
	(11.48)	(5.27)	(3.22)	(0.86)	(0.09)	(20.91)
Centrally managed economies	1 056	1 167	1 127	1 007	661	5 018
	(1.33)	(1.47)	(1.42)	(1.27)	(0.83)	(6.31)
Middle East oil exporters	656	319	162	0	0	1 137
	(0.83)	(0.40)	(0.20)	(0.00)	(0.00)	(1.43)
Newly industrialising	10 474	2 334	5 728	2 161	74	20 771
countries	(13.18)	(2.94)	(7.21)	(2.72)	(0.09)	(26.13)
Less developed countries	991	632	268	0	38	1 929
	(1.25)	(0.80)	(0.34)	(0.00)	(0.05)	(2.43)
Others	0	71	110	50	0	231
	(0.00)	(0.09)	(0.14)	(0.06)	(0.00)	(0.29)
Total	41 084	15 202	17 047	5 311	841	79 485
	(51.69)	(19.13)	(21.45)	(6.68)	(1.06)	(100.00)

Notes 1. Figures in parentheses are percentages of grand total.
2. The blocs of countries constituting the main flag categories, except OECD, are set out in Table 2.3.

Sources Lloyd's Register of Shipping (1986). BTCE estimates.

TABLE 3.11 SHIP NUMBERS IN THE 1985-86 BULK SHIPPING VISITORS FLEET BY FLAG BY AGE

	Age (years)					
Flag bloc	*0.0-5.5*	*5.5-10.5*	*10.5-15.5*	*15.5-20.5*	*> 20.5*	*Total*
OECD	251	121	99	21	0	492
	(17.14)	(8.27)	(6.76)	(1.43)	(0.00)	(33.61)
Open registries	235	112	48	16	2	413
	(16.05)	(7.65)	(3.28)	(1.09)	(0.14)	(28.21)
Centrally managed economies	29	34	32	26	20	141
	(1.98)	(2.32)	(2.19)	(1.78)	(1.37)	(9.63)
Middle East oil exporters	16	9	5	0	0	30
	(1.09)	(0.61)	(0.34)	(0.00)	(0.00)	(2.05)
Newly industrialising countries	163	60	72	35	2	332
	(11.13)	(4.10)	(4.92)	(2.39)	(0.14)	(22.68)
Less developed countries	24	17	7	0	1	49
	(1.64)	(1.16)	(0.48)	(0.00)	(0.07)	(3.35)
Others	0	2	3	2	0	7
	(0.00)	(0.14)	(0.20)	(0.14)	(0.00)	(0.48)
Total	718	355	266	100	25	1 464
	(49.04)	(24.25)	(18.17)	(6.83)	(1.71)	(100.00)

Notes 1. Figures in parentheses are percentages of grand total.
2. The blocs of countries constituting the main flag categories, except OECD, are set out in Table 2.3.

Sources Lloyd's Register of Shipping (1986). BTCE estimates.

Comparisons with the world fleet

As was done in the foregoing ship size distribution analysis, two graphical comparisons of the world, port calls and visitors fleets have been prepared for the age distributions, and are set out in Figures 3.3 and 3.4. The aggregate proportions of ship numbers and tonnage represented by each of the five age categories have been used as the basis of comparison. These proportions are given in the final rows of Tables 3.8 to 3.13. An inspection of Figures 3.3 and 3.4 reveals the following:

- The port calls and visitors fleets consisted of much newer ships than would have been expected on the basis of the world fleet's age distribution. In fact, the age distributions of the visiting fleet and the world fleet were significantly different in a statistical sense at the 5 per cent level of significance. Appendix III details this statistical analysis. Visiting bulk ships up to 5.5 years of age accounted for at least 15 per cent more fleet tonnage and at least 14 per cent more fleet vessels than did the same aged ships within the world fleet distribution.

- Vessels of ages 5.5 to 10.5 years showed little variation between the three fleet distributions, whereas above 10.5 years of age, the world fleet accounted for relatively greater tonnage and ship numbers. The absolute differences between the three fleets, however, were not nearly as great as for the newest category of bulk ships.

DISTRIBUTIONS BY FLAG

From Tables 3.2 to 3.5 the following major conclusions can be drawn[5]:

- The 1985-86 port calls and visitors fleets were dominated by OECD vessels.

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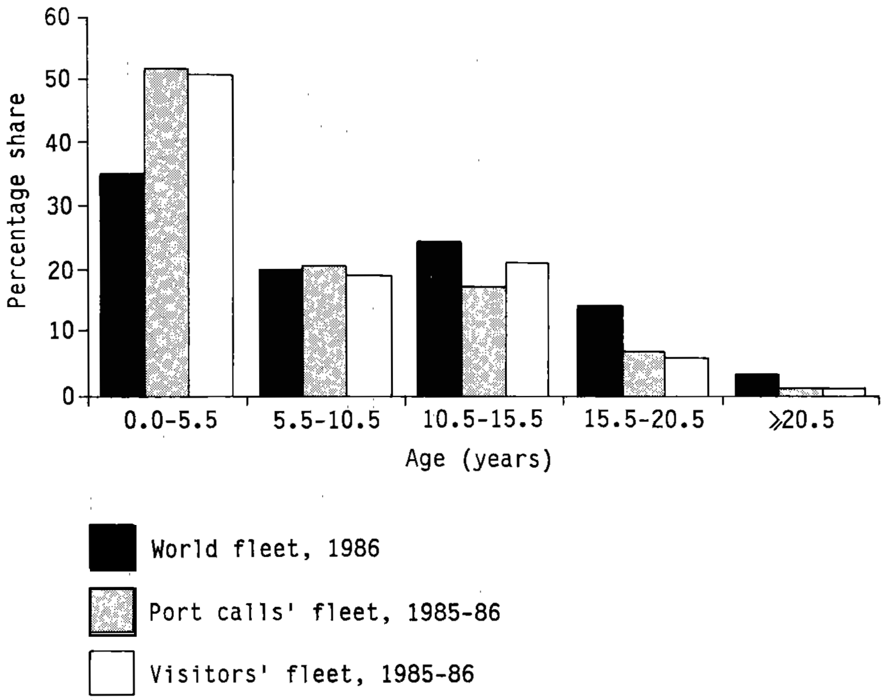
5. If each table is read horizontally, tonnage and ship numbers distributions are specified within a specific bloc of flags. The aggregate proportions are specified in the final column of each table. It will be noted that there are slight discrepancies between the aggregate proportions set out in the ship size distribution tables and those set out in the age distribution tables, for example, the first figures in the right hand column of Table 3.2 and Table 3.8 are 173 673 and 173 645 respectively. These differences resulted from gaps in the original data obtained from Lloyd's Register of Ships. The discrepancies, however, are very small and do not affect the distributions determined in any material way, especially the percentage distributions.



Source BTCE estimates.

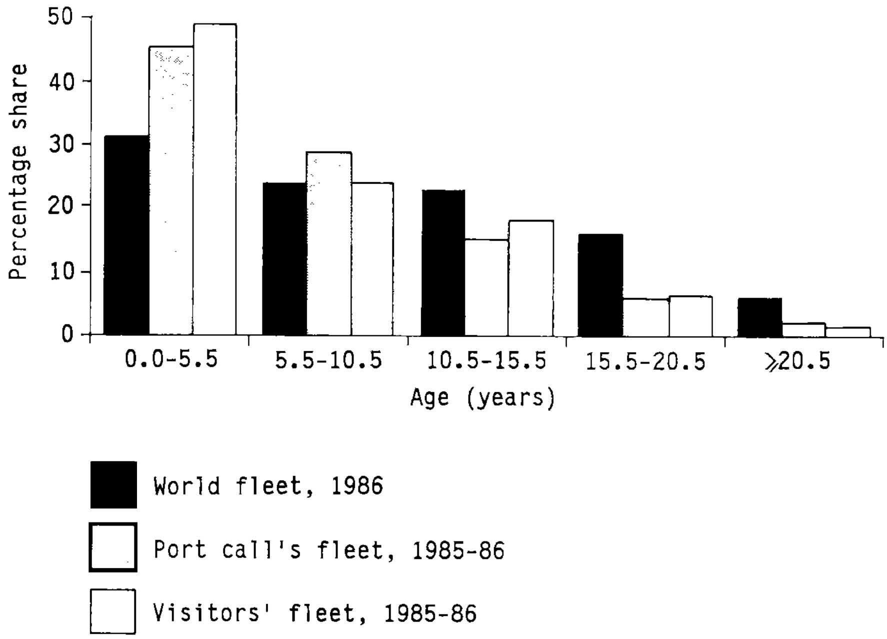
Figure 3.3 Comparison of bulk ship deadweight tonnage distributions by age

- Bulk ships of the newly industrialising countries (Hong Kong, Philippines, Singapore, South Korea and Taiwan) and FOC countries were the principal flag-bearers of the remaining visiting fleet.
- Of the total dry bulk tonnage that visited Australian ports during 1985-86, almost 30 per cent was generated by OECD vessels exceeding 100 000 dwt.

Comparisons with the world fleet

As for the ship size and age distributions, comparisons of aggregate flag distributions were made for the world, port calls and visitors fleets. The data for these comparisons originated from the percentage statistics given in the final column of Tables 3.2 to 3.7. Graphically, the results of this comparison are set out in Figures 3.5 and 3.6. The following major conclusions can be drawn from the comparison:

- The proportions of visiting ships bearing flags of OECD and newly industrialising countries far exceeded the corresponding



Source BTCE estimates.

Figure 3.4 Comparison of bulk ship numbers' distributions by age

proportions in the world bulk shipping fleet, both in terms of ship numbers and total tonnage. On the other hand, the world fleet proportions generally exceeded those of the visiting fleet for all other blocs of flags. Overall, the visiting fleet distributions of ship numbers and total tonnage were significantly different, in a statistical sense, from that expected according to the world fleet, as Appendix III shows.

- OECD vessels generally visited the Australian coast far more frequently than vessels of any other bloc of countries. This can readily be deduced from Figures 3.5 and 3.6, in which the port calls fleet proportions in terms of numbers and tonnage for OECD bulk ships were much greater than that of the visitors. For other flag blocs, the visitors fleet proportions invariably exceeded those of the port calls fleet.

DISCRIMINANT ANALYSIS

As an alternative to the percentage share comparisons (tabular, figurative and Chi-square tests) adopted in the preceding sections, it is possible to analyse simultaneously the three characteristics of dry

TABLE 3.12 TOTAL DEADWEIGHT TONNAGE OF THE WORLD BULK SHIPPING FLEET BY FLAG BY AGE, JUNE 1986
('000 dwt)

	Age (years)					
Flag bloc	*0.0-5.5*	*5.5-10.5*	*10.5-15.5*	*15.5-20.5*	*> 20.5*	*Total*
OECD	26 561	14 473	17 045	7 625	2 582	68 286
	(13.09)	(7.13)	(8.40)	(3.76)	(1.27)	(33.66)
Open registries	21 165	13 312	15 524	11 641	1 625	63 267
	(10.43)	(6.56)	(7.65)	(5.74)	(0.80)	(31.18)
Centrally managed economies	5 541	5 821	4 446	2 717	1 619	20 144
	(2.73)	(2.87)	(2.19)	(1.34)	(0.80)	(9.93)
Middle East oil exporters	1 117	425	390	101	86	2 119
	(0.55)	(0.21)	(0.19)	(0.05)	(0.04)	(1.04)
Newly industrialising	14 615	4 230	9 058	4 342	266	32 511
countries	(7.20)	(2.08)	(4.46)	(2.14)	(0.13)	(16.02)
Less developed countries	3 733	3 227	2 492	2 060	1 087	12 599
	(1.84)	(1.59)	(1.23)	(1.02)	(0.54)	(6.21)
Others	90	786	1 334	1 499	258	3 967
	(0.04)	(0.39)	(0.66)	(0.74)	(0.13)	(1.96)
Total	72 822	42 274	50 289	29 985	7 523	202 893
	(35.89)	(20.84)	(24.79)	(14.78)	(3.71)	(100.00)

Notes 1. Figures in parentheses are percentages of grand total.
2. The blocs of countries constituting the main flag categories, except OECD, are set out in Table 2.3.

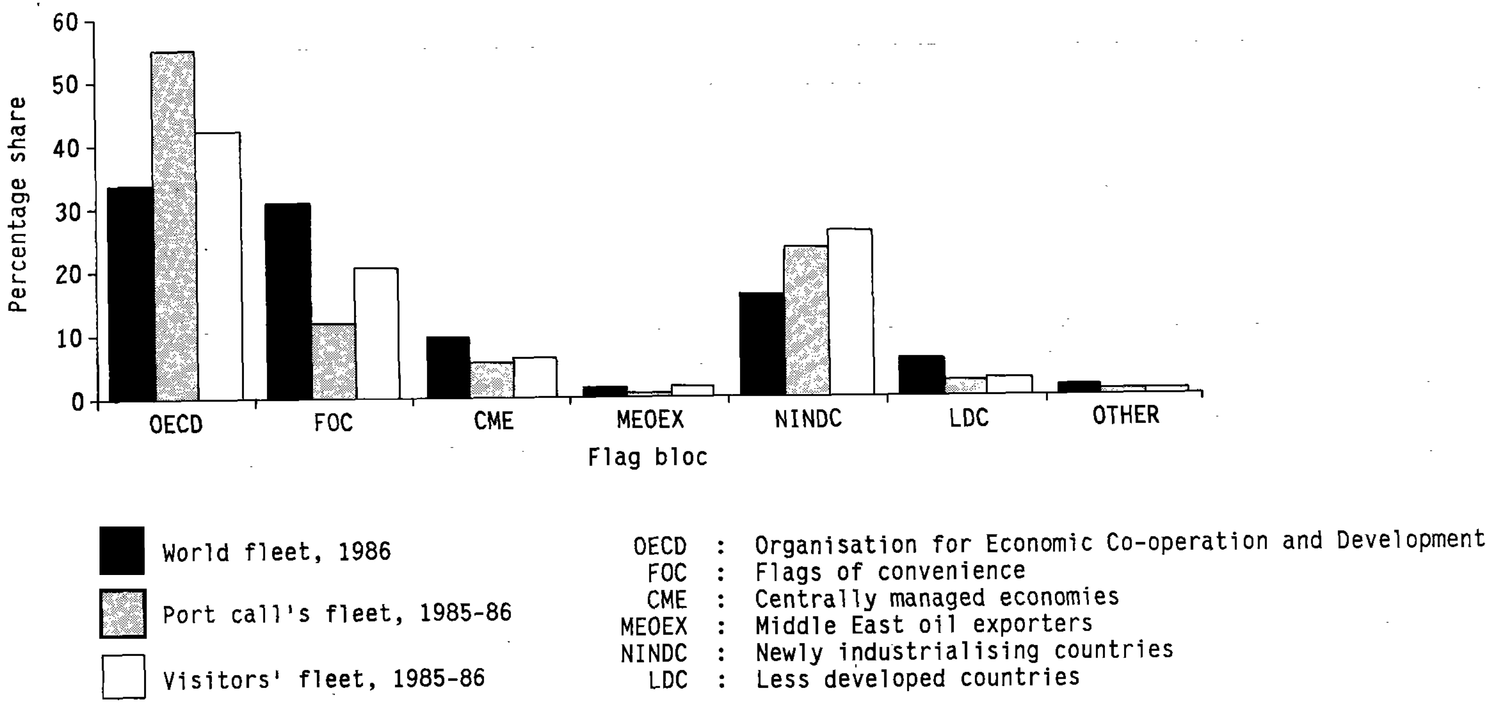
Sources Lloyd's Register of Shipping (1986). BTCE estimates.

TABLE 3.13 SHIP NUMBERS IN THE WORLD BULK SHIPPING FLEET BY FLAG BY AGE, JUNE 1986

	Age (years)					
Flag bloc	*0.0-5.5*	*5.5-10.5*	*10.5-15.5*	*15.5-20.5*	*> 20.5*	*Total*
OECD	459	327	329	201	103	1 419
	(9.48)	(6.75)	(6.79)	(4.15)	(2.13)	(29.31)
Open registries	545	381	337	291	66	1 620
	(11.26)	(7.87)	(6.96)	(6.01)	(1.36)	(33.46)
Centrally managed economies	149	185	151	106	71	662
	(3.08)	(3.82)	(3.12)	(2.19)	(1.47)	(13.67)
Middle East oil exporters	27	12	13	5	3	60
	(0.56)	(0.25)	(0.27)	(0.10)	(0.06)	(1.24)
Newly industrialising	249	121	147	95	9	621
countries	(5.14)	(2.50)	(3.04)	(1.96)	(0.19)	(12.83)
Less developed countries	93	87	65	68	36	349
	(1.92)	(1.80)	(1.34)	(1.40)	(0.74)	(7.21)
Others	5	17	36	43	10	111
	(0.10)	(0.35)	(0.74)	(0.89)	(0.21)	(2.29)
Total	1 527	1 130	1 078	809	298	4 842
	(31.54)	(23.34)	(22.26)	(16.71)	(6.15)	(100.00)

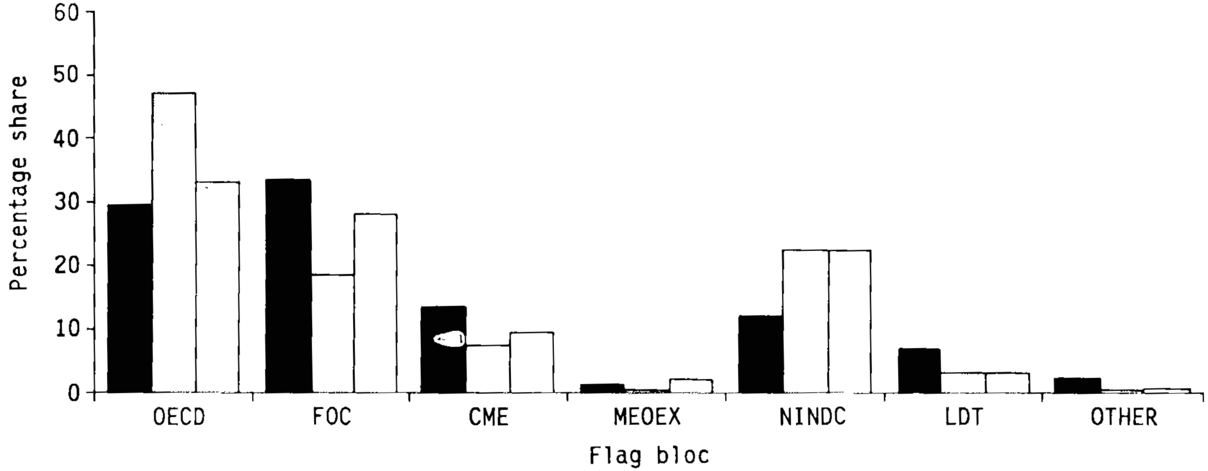
Notes 1. Figures in parentheses are percentages of grand total.
2. The blocs of countries constituting the main flag categories, except OECD, are set out in Table 2.3.

Sources Lloyd's Register of Shipping (1986). BTCE estimates.



Source BTCE estimates.

Figure 3.5 Comparison of bulk ship deadweight tonnage distributions by flag



World fleet, 1986
Port calls' fleet, 1985-86
Visitors' fleet, 1985-86

OECD : Organisation for Economic Co-operation and Development
FOC : Flags of convenience
CME : Centrally managed economies
MEOEX : Middle East oil exporters
NINDC : Newly industrialising countries
LDC : Less developed countries

Source BTCE estimates.

Figure 3.6 Comparison of bulk ship numbers' distribution by flag

bulk vessels previously described, that is, ship size, age and flag. Discriminant analysis is a statistical technique which enables such a simultaneous study of these three characteristics to be conducted.

The results of this technique's application to the data, which are summarised in detail in Appendix IV, show that size is the major discriminating variable between the visiting and non-visiting fleets, followed by age and flag. This discriminant analysis result is consistent with the results of the Chi-square tests. The results statistically reinforce the fact that dry bulk ships that were most likely to visit Australian ports during 1985-86 were large, recently constructed vessels flying flags of newly industrialising or OECD countries. This conclusion is consistent with Australia's overall international trading patterns. However, it must be remembered that the discriminant analysis results are aggregated and that the outcome for individually traded commodities might be quite different, as the following grain export analysis demonstrates.

DISTRIBUTIONS OF GRAIN CARRIERS

In the year ended June 1986, wheat exports contributed $2030 million to the total value of Australian export earnings (9 per cent) from 15.9 million tonnes exported; barley exports contributed $536 million (1.6 per cent) from 4.2 million tonnes exported; and sorghum $178 million (0.5 per cent) from 1.2 million tonnes exported (ABS 1986). These three commodities were the major export earners of all grain types during 1985-86, wheat being the second most important commodity after coal in its own right. There can be no doubt then, that grain exports which contributed over 11 per cent of Australia's total export earnings during 1985-86 are important to Australia's Balance of Payments position. The means by which such grain is exported is of equal importance in the context of this study.

Tables 3.14 to 3.17 detail the 1985-86 proportions of total grain export tonnage carried by various sized bulk ships, according to grain type, State of origin, geographical destination and vessel flag respectively. Figures V.1 to V.4 graphically present the same information. It should be noted these four distributions were based on incomplete and provisional data which only represented about 60 per cent of the total 1985-86 grain export tonnage. Nevertheless, there is no reason to suspect that the remaining 40 per cent would substantially distort the distributions. The major conclusions that can be drawn from these tabular and graphical information sources are as follows:

- Total grain export tonnage was dominated by wheat, to a lesser extent, barley and then sorghum.

TABLE 3.14 DISTRIBUTION OF 1985-86 AUSTRALIAN GRAIN EXPORTS TONNAGE BY GRAIN TYPE BY SIZE OF BULK CARRIER
(per cent)

	Vessel size ('000 dwt)					
Grain type	*0-40*	*40-60*	*60-80*	*80-100*	*>100*	*Total*
Wheat	45	22	8	0	0	75
Barley	11	6	1	0	0	18
Oats	<1	0	0	0	0	<1
Sorghum	6	<1	0	0	0	6
Maize	<1	<1	<1	0	0	<1
Other	<1	<1	0	0	0	<1
Total	62	28	10	0	0	100

Note Figures may not add to totals due to rounding.

Sources ABS (1986). Lloyd's Register of Shipping (1986). BTCE estimates.

TABLE 3.15 DISTRIBUTION OF 1985-86 AUSTRALIAN GRAIN EXPORTS TONNAGE BY STATE BY SIZE OF BULK CARRIER
(per cent)

	Vessel size ('000 dwt)					
State	*0-40*	*40-60*	*60-80*	*80-100*	*>100*	*Total*
New South Wales	13	9	4	0	0	26
Victoria	12	3	0	0	0	15
Queensland	15	2	1	0	0	18
South Australia	9	2	1	0	0	12
Western Australia	13	12	4	0	0	29
Total	62	28	10	0	0	100

Sources ABS (1986). Lloyd's Register of Shipping (1986). BTCE estimates.

TABLE 3.16 DISTRIBUTION OF 1985-86 AUSTRALIAN GRAIN EXPORTS TONNAGE BY DESTINATION BY SIZE OF BULK CARRIER
(per cent)

	Vessel size ('000 dwt)					
Destination	*0-40*	*40-60*	*60-80*	*80-100*	*>100*	*Total*
Europe	1	<1	0	0	0	1
Africa	2	<1	0	0	0	2
Americas	2	<1	0	0	0	2
Japan	12	<1	0	0	0	12
Middle East	12	16	4	0	0	32
South-East Asia	8	1	0	0	0	9
Other Asia	25	10	6	0	0	42
Total	62	28	10	0	0	100

Note Figures may not add to totals due to rounding.

Sources ABS (1986). Lloyd's Register of Shipping (1986). BTCE estimates.

- Ninety per cent of total grain exports was carried in bulk vessels of less than 60 000 dwt; 62 per cent of grain exports in vessels of less than 40 000 dwt.
- FOC vessels carried 35 per cent of the total grain tonnage, and nearly three-quarters of this amount exported by FOC ships was carried in vessels of less than 40 000 dwt. Bulk ships bearing flags of OECD countries, centrally managed economies and newly industrialising countries, in that order, were the most important carriers of grain exports after the FOC ships.
- Ports in New South Wales and Western Australia accounted for 55 per cent of Australia's total exported grain tonnage. Their real dominance, however, is reflected in the proportion (76 per cent) of the grain tonnage exported in vessels greater than 40 000 dwt, resulting directly from the deeper ports within these two States.
- In 1985-86, approximately three-quarters of Australia's total grain tonnage was exported to Middle Eastern and Asian countries. However, 95 per cent of the total grain tonnage carried in larger ships (greater than 40 000 dwt) was exported to these countries, implying the remaining world markets for Australian grain were supplied almost exclusively by smaller bulk carriers of less than 40 000 dwt.

TABLE 3.17 DISTRIBUTION OF 1985-86 AUSTRALIAN GRAIN EXPORTS TONNAGE BY FLAG BY SIZE OF BULK CARRIER
(per cent)

	Vessel size ('000 dwt)					
Flag bloc	*0-40*	*40-60*	*60-80*	*80-100*	*>100*	*Total*
OECD	11	6	3	0	0	20
Open registries	25	7	3	0	0	35
Centrally managed economies	10	5	<1	0	0	16
Middle East oil exporters	3	3	0	0	0	6
Newly industrialising countries	9	3	3	0	0	15
Less developed countries	4	4	0	0	0	8
Total	62	28	10	0	0	100

Notes 1. Figures may not add to totals due to rounding.
2. The blocs of countries constituting the main flag categories, except OECD, are set out in Table 2.3.

Sources ABS (1986). Lloyd's Register of Shipping (1986). BTCE estimates.

Fearnleys (1986a) estimated that total grain shipments from Australia during 1985 were distributed as follows:

- vessels less than 40 000 dwt accounted for 53 per cent;
- vessels 40 000 to 60 000 dwt accounted for 33 per cent; and
- vessels 60 000 to 80 000 dwt accounted for 14 per cent.

Based on the data contained in Tables 3.14 to 3.17, the distribution for 1985-86 was as follows:

- vessels less than 40 000 dwt accounted for 62 per cent;
- vessels 40 000 to 60 000 dwt accounted for 28 per cent; and
- vessels 60 000 to 80 000 dwt accounted for 10 per cent.

At the 5 per cent level of significance, these two distributions are not statistically different. However, there can be no doubt that the Australian export distribution is skewed significantly towards the small bulk carriers in comparison with Fearnley's (1986a) estimates of the 1985 size distributions of ships serving the major grain exporting areas of the world as set out in Table 3.18.

TABLE 3.18 DISTRIBUTIONS OF 1985 GRAIN SHIPMENTS BY EXPORTING AREA BY SIZE OF BULK CARRIER
(per cent)

Exporting Area	*Vessel size ('000 dwt)* 0-40	*40-60*	*60-80*	*80-100*	*>100*	*Total*
Australia	53	33	14	0	0	100
Argentina	27	34	39	0	0	100
Canada	38	22	29	4	7	100
USA	31	19	39	4	7	100
Others	44	30	22	0	4	100
World	36	24	33	2	5	100

Source Fearnleys (1986a).

TABLE 3.19 AGGREGATE LOADING FACTORS, 1985-86
(per cent)

Variable	*Vessel size ('000 dwt)* 0-40	*40-60*	*60-80*	*80-100*	*>100*	*Total*
Wheat	87	82	88	0	0	85
Barley	67	71	*	0	0	68
Sorghum	90	*	0	0	0	90
New South Wales	91	91	88	0	0	90
Victoria	87	76	*	0	0	84
Queensland	86	77	88	0	0	85
South Australia	65	64	40	0	0	63
Western Australia	81	75	90	0	0	80

* Subject to sampling, variability too high for most practical purposes.

Sources ABS (1986). Lloyd's Register of Shipping (1986). BTCE estimates.

Loading factors

Distributions of 1985-86 aggregate loading factors were calculated by ship size, by grain type and by State of origin.[6] Some of the most interesting and most reliable results are set out in Table 3.19.

It will be seen that these loading factors are not obvious functions of the deadweight tonnage of the grain carrying vessel. However, loading factors do clearly vary with:

- the grain commodity loaded; and
- the port of loading.

These loading factors, it must be stressed, are highly aggregated statistics and will be affected by such factors as the extent of two-port loading and industrial disputation. Nevertheless, evidence of two-port loadings in the national data was not significant and industrial problems on the Australian waterfront during 1985-86 were relatively small in comparison with former years. Overall then, the absolute differences in the levels of loading factors for grain types and State of loading, must be functions of other factors, such as port infrastructure (draught restrictions preclude high loading factors) and physical characteristics of the commodity (densities of the various grains may mean volume limits will be attained before tonnage limits are reached). For example, in South Australia, the lower aggregate loading factors are direct results of:

- port draught restrictions (which may account for the relatively higher incidence of two-port loading in this State); and
- a high proportion of grain exports being barley, that is, a low density grain.

SUMMARY

This chapter has shown that dry bulk ships employed in Australian bulk trades tend to be larger and newer than the world bulk fleet. In addition, OECD flags were dominant among visiting bulk carriers. Statistical analysis indicates that size is the most important factor

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6. Aggregate loading factors are defined as the weighted average of the individual loading factors for each vessel (an individual loading factor equals grain tonnage loaded per vessel dwt), where the weights are the grain tonnage loaded, relative to the total tonnage loaded in that grain category being considered.

discriminating between ships visiting Australia and the world fleet followed by age and flag.

A large proportion (62 per cent) of Australia's grain exports in 1985-86 were carried in ships of less than 40 000 deadweight tonnes. This is a much higher proportion than experienced by other grain exporting countries. Draught restricted ports, especially in South Australia, provide much of the explanation. Draught, or possibly storage limitations in importing countries, might also be a factor.

CHAPTER 4 FUTURE DISTRIBUTION OF THE WORLD FLEET

In Chapters 2 and 3 the evolution and the current distribution of the world bulk fleet, as well as the distribution of the fleet which visited Australia, were examined in detail. This chapter extends that analysis by forecasting the future development of the world bulk fleet under three separate sets of scenarios regarding new deliveries into, and exits from, the fleet.

It should be emphasised that to forecast the future size and composition of the world bulk fleet is a hazardous task for any researcher as there are many influences, predictable and unpredictable, on new order and scrappage rates. Nevertheless, demand and supply-side forecasts for bulk shipping are important determinants of capital investment decision-making by current or prospective shipowners. Therefore, forecasting the future distribution of the world fleet has been incorporated into this study to complement the analysis of capital costs which form a significant part of a shipowner's operating cost structure, as will be seen in Chapters 8, 9 and 10. Changes in the size and composition of the fleet are clearly of importance to shippers and port authorities as well, but such interest is not examined in detail in this Paper.

The world bulk fleet has been progressing towards the use of larger ships for at least 15 years. This has occurred through an increase in the number and proportion of larger ships in the fleet and through a decline in the number and proportion of smaller ships. For example, the number of ships larger than 80 000 dwt increased from 139 (4 per cent) in January 1977 to 343 (7 per cent) in January 1987. Over the same period, the number of ships in the range 10 000 to 18 000 dwt declined from 681 (20 per cent) to 557 (12 per cent) (Fearnleys 1987, 5).

NEW DELIVERIES TO THE FLEET

New deliveries to the bulk fleet have exhibited considerable volatility over the last decade varying from a minimum of 3.6 million dwt in 1979 to a maximum of 14.7 million dwt in 1985. New deliveries declined by 21 per cent in 1986 and prospects for 1987 are for a further decline.

TABLE 4.1 NEW DELIVERIES OF BULK SHIPS FOR 1984, 1985, 1986
('000 dwt)

Vessel size	*Year* 1984	1985	1986
10-18	100	100	100
	(0.7)	(0.7)	(0.9)
18-40	6 700	6 300	2 700
	(47.2)	(42.9)	(23.1)
40-50	1 700	3 800	1 800
	(12.0)	(25.9)	(15.4)
50-60	300	200	300
	(2.1)	(1.4)	(2.6)
60-80	3 300	1 100	1 600
	(23.2)	(7.5)	(13.7)
80-100	100	100	0
	(0.7)	(0.7)	(0.0)
100-150	1 100	500	1 100
	(7.7)	(3.4)	(9.4)
>150	900	2 600	4 100
	(6.3)	(17.7)	(35.0)
Total	14 200	14 700	11 700
	(100.0)	(100.0)	(100.0)

Notes 1. Figures in parentheses are percentages.
2. Figures may not add to totals due to rounding.

Source Fearnleys (1985, 1986b, 1987).

Table 4.1 illustrates the distribution of new deliveries for the three years 1984 to 1986. It is apparent that the distribution of new ships is undergoing rapid transition with a major increase in the proportion of ships larger than 150 000 dwt (from 6.3 per cent to 35.0 per cent) and a decline in ships less than 40 000 dwt (from 47.9 per cent to 24.0 per cent). Table 4.2 illustrates expected new deliveries for 1987.

TABLE 4.2 SCHEDULED NEW DELIVERIES FOR 1987

Vessel size ('000 dwt)	*Number of vessels*	*Total tonnage ('000 dwt)*
10-30	62	1 441
30-50	59	2 243
50-80	27	1 757
80-100	1	81
>100	33	5 337
Total	182	10 859

Source Drewry (1987a, 35).

The data in Tables 4.1 and 4.2 formed the basis for assumed new deliveries in the three scenarios which are:

Scenario 1 - 1986 new deliveries maintained through to the year 2000.

Scenario 2 - expected 1987 new deliveries assumed for 1987 and 1988 and then increasing by 10 per cent in 1989 and 1990 and remaining constant thereafter.

Scenario 3 - a new delivery schedule which is a composite of those experienced in 1984 to 1986 and maintained at a constant level through to the year 2000 (Table 4.3).

The distribution of new deliveries in Scenario 3 is based on the average of new deliveries in 1984 to 1986 with adjustments to reflect current trends. For example, the tonnage assumed for ships above 150 000 dwt is higher than the average to reflect increased building activity in this range. The 95 000 dwt assumed for the 80 000 to 100 000 dwt range exceeds the average but this is merely because the average (67 000 dwt) is not part of the range.

TABLE 4.3 NEW DELIVERIES USED IN THE FORECAST FOR SCENARIO 3

Vessel size ('000 dwt)	*Total tonnage ('000 dwt)*	*Per cent*
10-20	108	0.8
20-40	4 050	30.0
40-50	2 362	17.5
50-60	270	2.0
60-80	2 025	15.0
80-100	95	0.7
100-150	1 215	9.0
>150	3 375	25.0
Total	13 500	100.0

Source BTCE estimates.

EXITS FROM THE FLEET

Ships can exit from the bulk fleet by any of three mechanisms:

- sales for scrap
- casualties
- conversion of bulk carriers to combined carriers.

By far the most dominant mechanism is the sale for scrap and the analysis that follows is based on this mechanism.

Drewry's Shipping Statistics and Economics (1985b, 1986, 1987a) was the primary source of data on sales for scrap. This publication lists individual ships giving both the year of construction and size in dwt. These data enabled a distribution of ships sold for scrap to be developed, by size and year of construction, for the years 1984 to 1986. Another publication of the Institute of Shipping Economics and Logistics (1985, 1986, 1987) contained separate distributions of ships sold for scrap by size and by year of construction. Given the totals in each size category and age category, an approximate distribution by both size and age was constructed.

Distributions were constructed for each of the years 1984, 1985 and 1986 and these were then combined into a single distribution by averaging the three individual distributions. Because the size distribution is undergoing reasonably rapid change, it is unlikely that a distribution based on tonnes scrapped in the mid-1980s would be a useful description of tonnes scrapped in the 1990s. However, the proportion of tonnage scrapped in each size and age category is more likely to remain stable. For this reason, the distribution based on tonnage was converted to a distribution based on proportions of each size and age category.

Very few ships greater than 100 000 dwt were scrapped during the years 1984 to 1986. Changes were made to the scrapping distribution to include a scrapping rate for ships of this size. The proportions chosen were the averages of the proportions for the other size categories within the same age category.

The resulting distribution of scrapping proportions formed the basis for the assumed scrapping rates in the three scenarios. The computer programs used for the forecasting could be readily amended to adjust the rates to produce any scrapping level required.

The assumed scrapping rates used in the three scenarios are:

Scenario 1 - scrapping rates maintained at 1986 rates through to the year 2000.

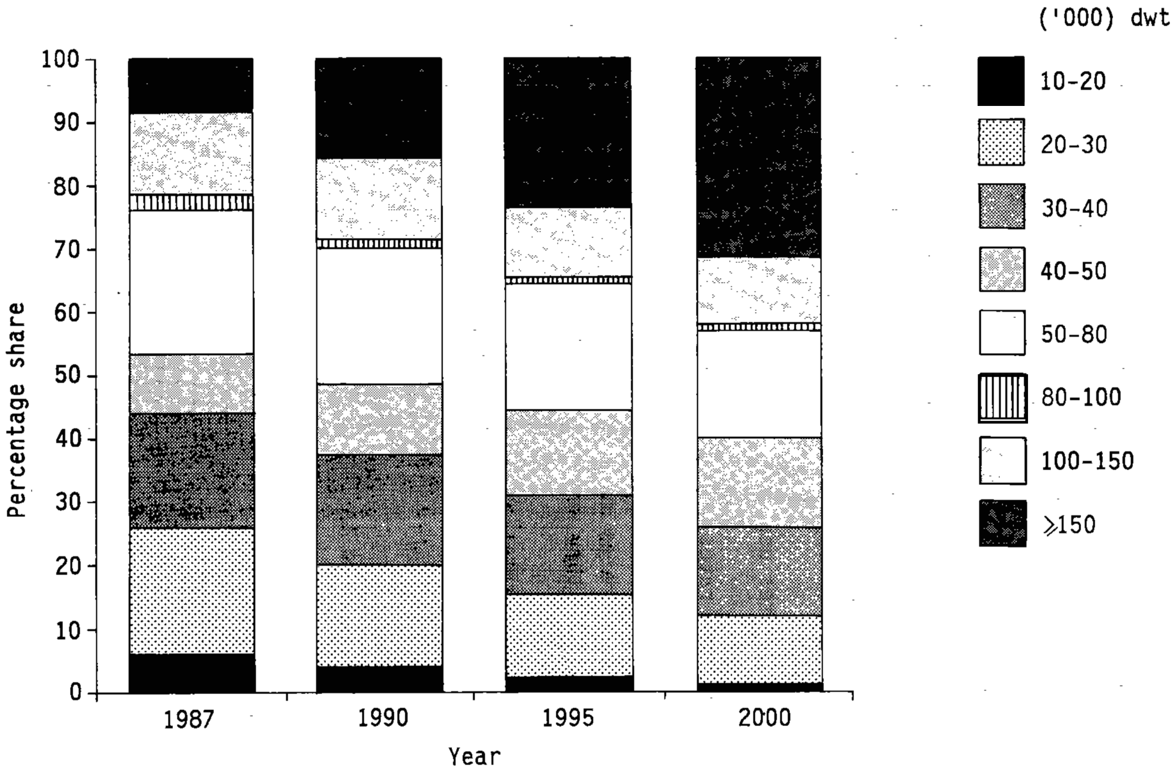
Scenario 2 - scrapping rates maintained at 1986 rates until 1990. After 1990 they were assumed to decline by 30 per cent.

Scenario 3 - scrapping rates were assumed to be maintained at the average 1984 to 1986 rates through to 2000.

RESULTS

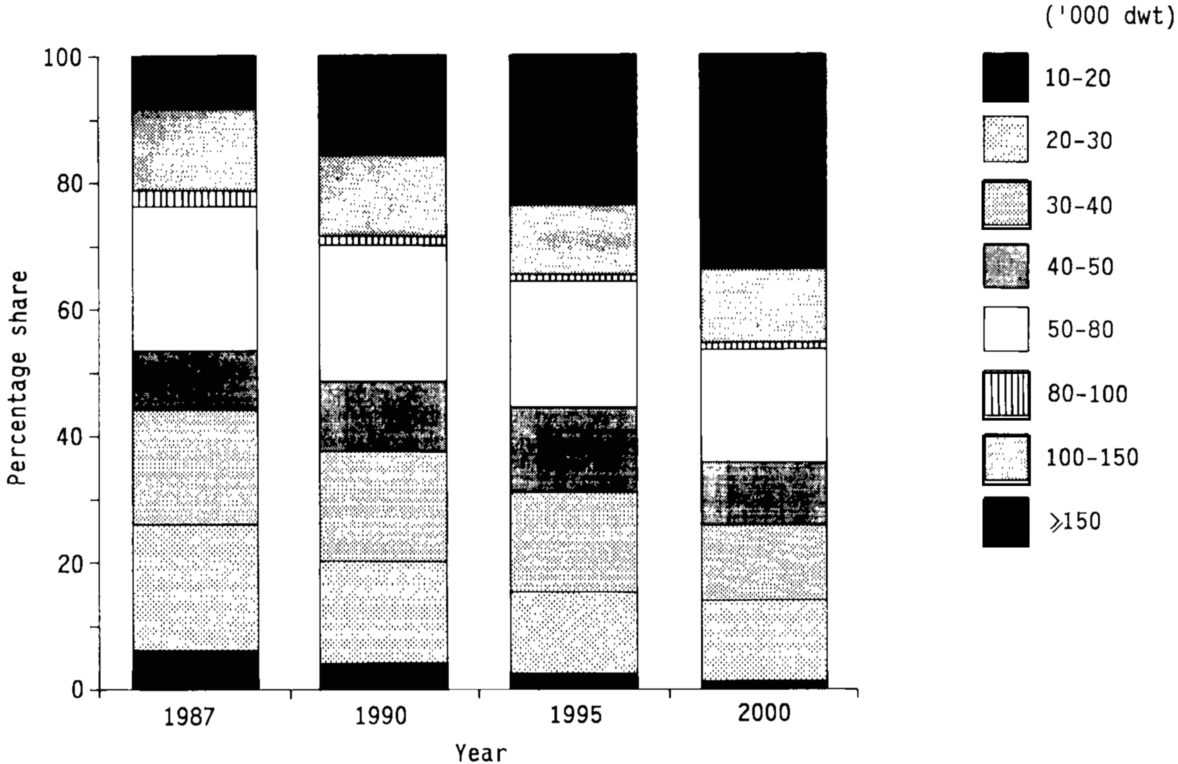
The forecasts are illustrated in Tables 4.4 and 4.5 and in Figures 4.1 to 4.3.

All of the scenarios result in low or only moderate growth. Scenario 3 has the highest growth rate, averaging 2.2 per cent per annum over the forecast period. The most obvious characteristic of the forecasts is the trend towards larger ships. The average size of the bulk ships larger than 10 000 dwt was 40 900 dwt on 1 January 1987 (Fearnleys 1987, 12). This present analysis indicates that by the year 2000 the average ship size will have increased to 57 000, 59 000 and 50 000 dwt under Scenarios 1, 2 and 3 respectively.



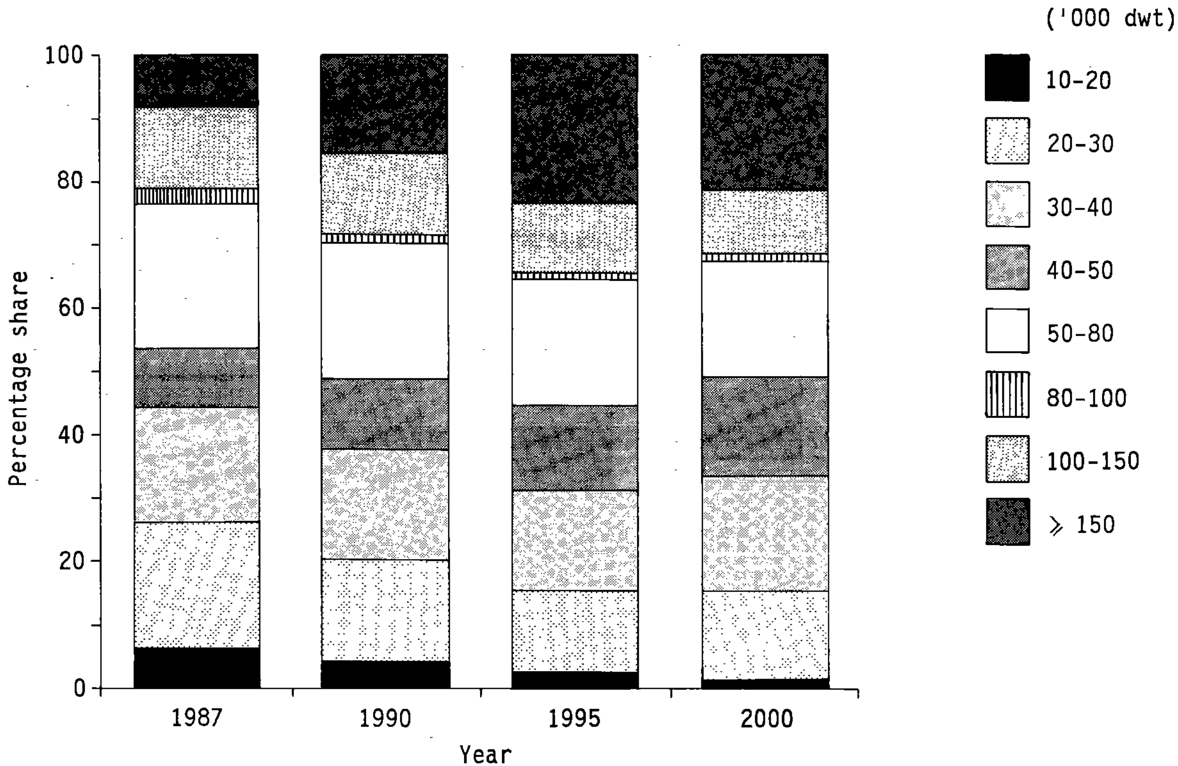
Source BTCE estimates.

Figure 4.1 Forecast deadweight tonnage distribution of the world bulk fleet, scenario 1



Source BTCE estimates.

Figure 4.2 Forecast deadweight tonnage distribution of the world bulk fleet, scenario 2



Source BTCE estimates.

Figure 4.3 Forecast deadweight tonnage distribution of the world bulk fleet, scenario 3

TABLE 4.4 FORECAST TOTAL DEADWEIGHT TONNAGE DISTRIBUTION OF THE WORLD BULK FLEET

Vessel size ('000 dwt)	*Scenario*	*Year* *1987*	*1990*	*1995*	*2000*
		(million dwt)			
10-20	1	11.9	8.1	5.2	2.8
		(6.1)	(4.1)	(2.5)	(1.3)
	2	11.9	8.1	6.1	3.9
		(6.1)	(4.1)	(2.7)	(1.6)
	3	11.9	9.2	6.4	3.9
		(6.1)	(4.2)	(2.6)	(1.5)
20-30	1	39.4	32.3	26.8	23.3
		(20.1)	(16.2)	(12.9)	(11.0)
	2	39.4	32.7	31.5	30.1
		(20.1)	(16.4)	(14.0)	(12.5)
	3	39.4	38.5	36.9	35.5
		(20.1)	(17.4)	(15.1)	(13.7)
30-40	1	35.3	34.3	32.8	29.2
		(18.0)	(17.3)	(15.8)	(13.8)
	2	35.3	33.1	31.4	27.2
		(18.0)	(16.6)	(13.9)	(11.3)
	3	35.3	40.9	45.5	47.6
		(18.0)	(18.5)	(18.6)	(18.3)
40-50	1	18.4	22.2	27.4	29.3
		(9.4)	(11.2)	(13.2)	(13.9)
	2	18.4	20.6	24.0	24.6
		(9.4)	(10.4)	(10.7)	(10.2)
	3	18.4	26.1	34.6	40.4
		(9.4)	(11.8)	(14.2)	(15.6)
50-80	1	44.8	42.6	41.5	36.4
		(22.8)	(21.4)	(20.0)	(17.3)
	2	44.8	42.9	45.5	43.6
		(22.8)	(21.6)	(20.2)	(18.1)
	3	44.8	47.7	49.3	47.9
		(22.8)	(21.6)	(20.2)	(18.5)

TABLE 4.4 (Cont.) FORECAST TOTAL DEADWEIGHT TONNAGE DISTRIBUTION OF THE WORLD BULK FLEET

Vessel size ('000 dwt)	*Scenario*	*Year* 1987	1990	1995	2000
		(million dwt)			
80-100	1	4.1	3.3	2.5	2.0
		(2.1)	(1.7)	(1.2)	(0.9)
	2	4.1	3.3	2.9	2.5
		(2.1)	(1.7)	(1.3)	(1.0)
	3	4.1	3.7	3.1	2.6
		(2.1)	(1.7)	(1.6)	(1.0)
100-150	1	26.1	25.6	23.2	22.1
		(13.3)	(12.8)	(11.2)	(10.5)
	2	26.1	26.0	27.0	27.9
		(13.3)	(13.1)	(12.0)	(11.6)
	3	26.1	27.6	36.7	25.9
		(13.3)	(12.5)	(10.9)	(10.0)
>150	1	16.1	30.5	48.5	65.9
		(8.2)	(15.3)	(23.3)	(31.2)
	2	16.1	32.0	57.0	81.3
		(8.2)	(16.1)	(25.3)	(33.7)
	3	16.1	27.4	41.8	55.8
		(8.2)	(12.4)	(17.1)	(21.5)
Totals	1	196.0	198.9	207.8	210.9
		(100.0)	(100.0)	(100.0)	(100.0)
	2	196.0	198.6	225.2	241.0
		(100.0)	(100.0)	(100.0)	(100.0)
	3	196.0	221.0	244.3	259.6
		(100.0)	(100.0)	(100.0)	(100.0)

Notes 1. Figures in parentheses are percentages.
2. Figures may not add to totals due to rounding.

Sources Fearnleys (1987). BTCE estimates.

TABLE 4.5 FORECAST AGE DISTRIBUTIONS OF THE WORLD BULK FLEET
(per cent)

Age (years)	*Scenario*	*Year* 1987	1990	1995	2000
0-5	1	35.9	29.7	28.5	28.0
	2	35.9	29.6	29.6	27.6
	3	35.9	30.7	27.8	26.2
6-10	1	20.8	33.2	28.3	27.9
	2	20.8	33.2	26.0	27.5
	3	20.8	29.9	27.7	26.1
11-15	1	24.8	20.0	29.9	26.6
	2	24.8	10.1	28.1	23.6
	3	24.8	18.5	26.1	25.2
16-20	1	14.8	13.5	10.2	15.0
	2	14.8	13.5	11.4	16.5
	3	14.8	15.2	11.4	16.3
>20	1	3.7	3.6	3.2	2.5
	2	3.7	3.7	4.9	4.8
	3	3.7	5.7	6.9	6.3
	1,2,3	100.0	100.0	100.0	100.0

Note Figures may not add to totals due to rounding.

Source BTCE estimates.

Ships greater than 100 000 dwt would comprise 31.5 per cent of the fleet tonnage under Scenario 3 but this proportion would be higher at 41.7 per cent and 45.3 per cent under Scenarios 1 and 2 respectively.

Panamax ships would decline in importance under all scenarios, dropping from 22.8 per cent of fleet tonnage to around 18 per cent. However, the total tonnage of such ships would increase absolutely under the higher growth Scenario 3 and would decline under the low growth Scenario 1.

The trend to larger ships would be at the expense of the smaller vessels less than 40 000 dwt, the tonnage of which would generally decline within each size category as a proportion of the fleet tonnage and in absolute terms in Scenarios 1 and 2. In Scenario 3, absolute tonnage in the 30 000 to 40 000 dwt range would increase.

Scenario 3 is based on the assumption that new deliveries throughout the analysis period are, with some amendments, equal to the average of new deliveries during the years 1984 to 1986. However, this period witnessed a marked increase in deliveries of ships greater than 150 000 dwt; Tables 4.1 and 4.2 indicate that this trend is continuing. Averaging new deliveries during the three years would tend to understate the trend to larger ships. This was corrected to some extent in Scenario 3 by choosing a value for new deliveries in this deadweight range above the average. Nevertheless, it seems reasonable to conclude that the tonnage proportion of ships larger than 100 000 dwt forecast under Scenario 3 is a lower limit. As a corollary, the tonnage proportion of smaller ships forecast under Scenario 3 is likely to be an upper limit.

Fearnleys (1987) have presented a forecast for 1990 based on known and expected orders, and estimates of scrappings and adjustments. Their forecast is shown in Table 4.6.

TABLE 4.6 FEARNLEYS FORECAST TOTAL DEADWEIGHT TONNAGE DISTRIBUTION FOR 1990

Vessel size ('000 dwt)	*Total tonnage (million dwt)*
10-50	91.1
50-80	41.1
80-200	45.2
>200	6.3
Total	183.7

Source Fearnleys (1987).

The forecasts presented in Table 4.4 are more optimistic than those in Table 4.6. However, forecasts derived from Scenarios 1 and 2 are more consistent with those of Fearnleys than does Scenario 3. This adds weight to the comments that Scenario 3 gives a lower limit to the tonnage proportion of large ships in the fleet and an upper limit to the tonnage proportion of smaller ships.

The age distribution is not as sensitive to the assumptions as is the size distribution. Scenarios 2 and 3 show an increase in the proportion of ships over 15 years old in the year 2000. Scenario 1 shows a small decrease. All scenarios show a decline in the proportion of ships less than 5 years old and an increase in the proportion of ships between 6 and 10 years old. The net effect on average ship age is small. The average age is between 9 and 10 years for all scenarios in the year 2000.

Finally, the forecasts being based on trends in the years 1984 to 1986 should only be considered as rough estimates. A change in market conditions can greatly affect the volume of new deliveries and scrappings over a relatively short period of time and thus greatly affect the outcome for the forecast years. However, the forecasts are useful in indicating trends in the distribution of ship size.

SUMMARY

The future size and distribution of the bulk ship fleet depends on the newbuilding rate and the rate at which ships exit the fleet. General conclusions that can be drawn from the analyses presented in this chapter are that large ships (greater than 150 000 deadweight tonnes) will form an increasing proportion of the bulk fleet, and that smaller ships (less than 40 000 deadweight tonnes) will form a decreasing proportion of the fleet. As a consequence, the average ship size will increase from 41 000 deadweight tonnes in 1987 to somewhere in the range of 50 000 to 60 000 deadweight tonnes by the year 2000. The average age of the fleet is likely to remain in the range of nine to ten years.

CHAPTER 5 TRENDS IN BULK SHIPPING TECHNOLOGY

Chapters 5 and 6 are devoted to technological change, and in particular, the impacts of such change on the levels of the two principal factors of production underlying the industry - capital and labour. In this chapter, developments in bulk shipping capital, past, present and future, are examined in detail.

During the last decade there have been significant changes to the design of bulk ships. An important factor driving the direction of change has been the incentive to use larger ships and the lower transport costs per tonne derived from them. Channel depth is a major constraint in many ports on the size of ship that can be accommodated. One approach to overcome this constraint is to reduce the design draught of a ship by increasing the breadth while maintaining the deadweight capacity.

Rapid increases in oil prices in the 1970s, especially in 1973 and 1979, increased ship operating costs substantially. Ship designers reacted to these cost increases by improving hull and propeller designs, hull coatings and the efficiency of engines.

In 1980, the then Bureau of Transport Economics published the results of an analysis of ships' characteristics (Piko 1980). This analysis was based on ships recorded in Lloyd's Register of Ships in 1977. That analysis related ship dimensions and power requirements to the deadweight tonnage of the ship. It is apparent that, in view of the design trends referred to previously, the relationships published in 1980 may no longer be valid for ships built since 1977. This is supported by the fact that 42 per cent of the bulk ships on Lloyd's Register of Ships as at June 1986 were built after 1977.

This chapter describes the analysis the BTCE has undertaken of ships in the June 1986 Lloyd's Register of Ships and compares the results with those obtained in the Bureau's analysis (Piko 1980). It will be seen from this analysis and from other sources, that bulk ships are becoming:

- shorter
- wider
- shallower
- more fuel efficient.

REGRESSION ANALYSIS

The data

The data on which the analyses were based were generally obtained from Lloyd's Register of Ships, June 1986. The Register allows for a comprehensive set of information for each ship but not all ships have the complete set recorded. The items in the Register used for this analysis and the definitions of those items used by Lloyds are:

- deadweight - the weight in tonnes of cargo, stores, fuel, passengers and crew carried by the ship when loaded to her maximum summer loadline;
- overall length - the extreme length of the ship and if the ship has a bulbous bow, the overall length recorded includes any protrusion of that bow;
- extreme breadth - the maximum breadth to the outside of the ship's structure;
- maximum draught - in most cases this is the maximum summer draught amidships, but in some ships of special construction, the maximum draught is at the aft end and then this figure is recorded;
- power - for ships classed in accordance with Lloyd's Register, the power recorded is the total maximum designed shaft power approved, but for other ships the power recorded is the total maximum service power as specified by the owners or as obtained from other reliable sources;
- speed in knots - the speed the ship is stated to be capable of maintaining at sea in normal weather and at normal service draught; and
- tonnes of fuel per day - fuel consumption as stated by the owners or as obtained from other reliable sources.

The reliability of the data is not uniform across these items. Length, breadth, draught and power were reported in the Bureau study as having good to very good reliability (Piko 1980, 6). Deadweight and speed data were described, in the same study, as being 'acceptable for analysis purposes'. Data on fuel consumption were not expected to be as reliable, principally because the conditions under which the data were obtained are not well defined. It is not clear from the definition used by Lloyds at what speed or under what load conditions the stated consumption was achieved. The unreliability of this item was confirmed when an analysis of specific fuel consumption was undertaken. For this reason engine performance data, as reported in industry journals, was assembled as well and was used in the final analysis of specific fuel consumption.

In the Piko study the data used were limited to those ships for which all data items were recorded. A similar approach was adopted in the present study. The development of relationships involving deadweight tonnage , year of construction, length, breadth, draught or power were limited to those ships for which all data items were recorded. The Piko analysis also ignored those ships for which more than one vessel type category was recorded. Similarly, the analysis in this study was limited to those ships recorded only as dry bulk carriers.

Application of the above restrictions resulted in a sample of 3435 ships. An examination of the data showed that obvious errors had occurred in the recording of the power of some ships in the sample. Generally, this took the form of a digit omitted from the data item. These errors were easily rectified as ships' engines are generally manufactured in discrete sizes so that the missing digit could be identified by examining the data for other ships of similar size.

Fuel consumption in tonnes per day was one further data item required for the analysis. This Lloyd's Register item exhibited considerable variability for ships which appeared from the data to be of similar size, power and speed. Current fuel efficient ship engines can achieve a specific fuel consumption rate of approximately 165 grams per kilowatt-hour. However, the minimum rate estimated from the data sample using the recorded power and recorded tonnes per day was less than 90 grams per kilowatt-hour. One can conclude that either the recorded data are in error or the ships with exceptionally low implied specific fuel consumption rates must be operating at considerably less than full power.

An example of the engine options available to a shipowner for a 40 000 dwt bulk carrier is presented in Table 5.1.

Calculating specific fuel consumption on the basis of maximum continuous rating gives a low and unreliable indicator of the specific fuel consumption rate based on actual service power. The example suggests that estimated specific fuel consumption rates of less than 150 grams per kilowatt-hour are probably based on engines for which the service power is substantially less than the maximum continuous rating.

TABLE 5.1 EFFECT OF ENGINE CHOICE AND POWER DEFINITION ON ESTIMATED SPECIFIC FUEL CONSUMPTION

Engine model	*Fuel consumption (t/d)*	*Engine MCR[a] (kw)*	*Specific fuel consumption[b] (g/kw-h)*	*Service power (kw)*	*Specific fuel consumption[c] (g/kw-h)*
1	25.2	9 030	116	5 950	176
2	25.2	9 540	110	5 960	176
3	25.5	7 320	145	6 090	174
4	24.2	10 980	92	5 950	169

a. Maximum continuous rating.
b. Estimated using MCR.
c. Estimated using service power.

Source Motor Ship (1987b).

So that only ships which operated at near normal engine operating conditions (85 to 90 per cent of maximum continuous rating) were included, all ships with an implied specific fuel consumption rate of less than 150 grams per kilowatt-hour were ignored. When this criterion was applied, together with the exclusion of ships for which no tonnes per day were recorded, the data sample for analysis of specific fuel consumption was reduced to 1626 ships. This sample was further reduced by including only those ships built after 1973. While fuel efficiency has always been of concern to engine designers and shipowners, it was assumed that after the first oil crisis, engine fuel efficiency became a much more important consideration. This further reduced the Lloyd's Register sample to 993.

The regression models

The models used in this analysis were designed to be used in other analyses undertaken by the BTCE. For this particular purpose it was convenient to use deadweight tonnage as an independent variable representing the size of the ship. A second purpose was to investigate the trends in ship design. Age of the ship, relative to 1986, was used as an independent variable to investigate which trends, if any, may have occurred. In addition, speed was used as an independent variable in the equation estimating the power of the engines installed in the ship. The dependent variables, being the dimensional characteristics of a ship (length, breadth and draught) together with power and specific fuel consumption, were chosen as equally important alternatives; no one estimated relationship was therefore intended to be superior to another. Generally, the models took the following form, where c_0 to c_3 were the coefficients to be estimated:

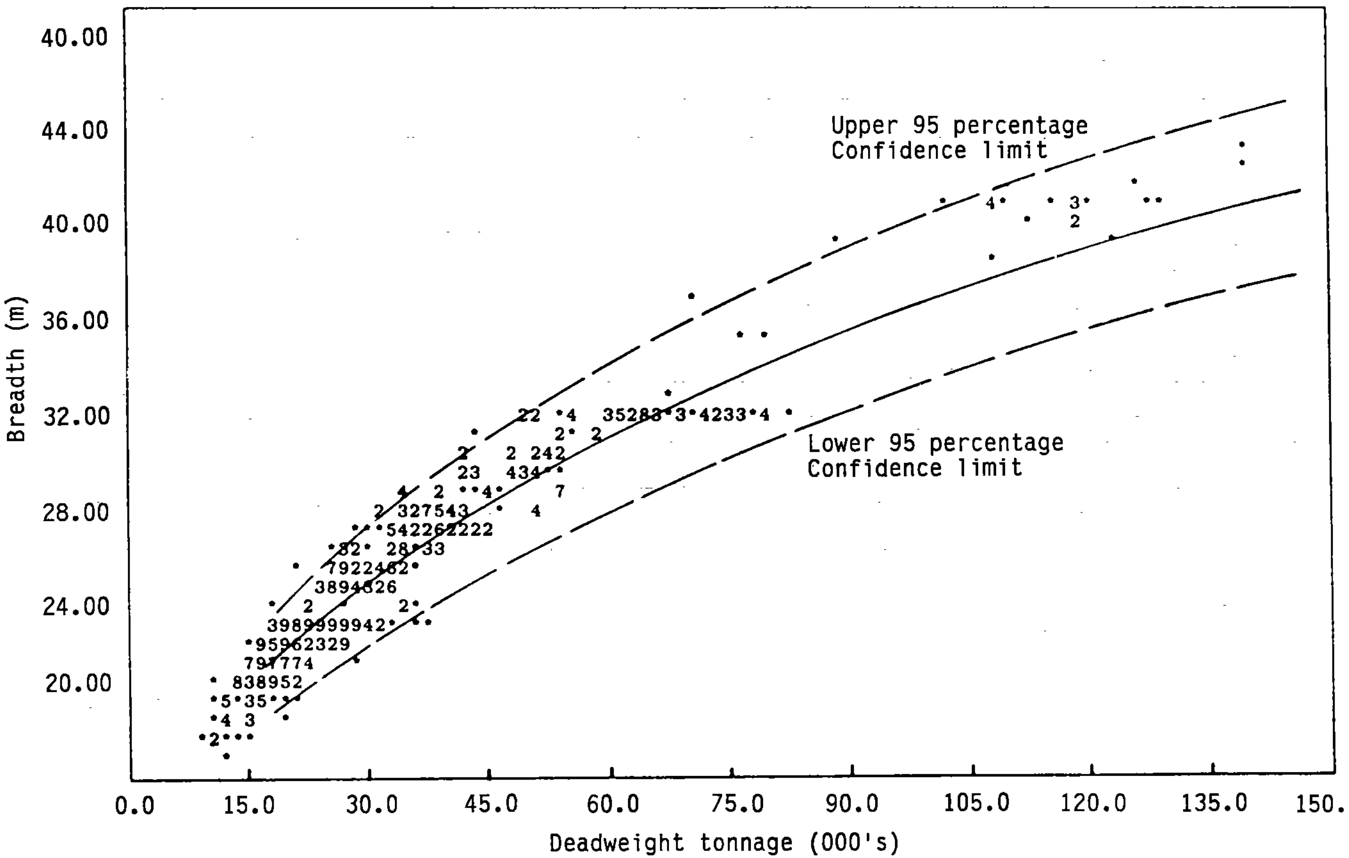
$$\ln\text{(dependent variable)} = c_0 + c_1 \ln \text{DWT} + c_2 \text{AGE} + c_3 \text{SPEED}$$

There is no fixed technical relationship between the size of a ship, as expressed by its deadweight capacity, and its physical dimensions. Rather, the designer has a range for each of the principal dimensions from which to choose. Financial considerations would tend to narrow the range of options. Some combinations of dimensions tend to result in lower capital costs than others. For example, the hull of a shorter ship tends to be cheaper to construct than that of a longer ship for a given deadweight capacity.

Physical constraints on particular trade routes can provide further restrictions on the design envelope available to the designer. The Panama Canal forms the most important restriction in this respect. However, draught limitations in many ports have also influenced the trend towards broader ships with shallower draughts. The desire to build broader ships has no doubt been constrained by the equally critical need for ships on some trades to be able to transit the Panama Canal. The breadth of these ships has therefore been limited to 32.3 metres, the width of the Panama Canal at its narrowest point, and this constraint typically applies to ships of 50 000 to 80 000 dwt. Recognition of the limitation of the Panama Canal needs to be considered in the regression analysis, otherwise the estimates of the coefficients are likely to be biased.

This problem may have occurred in the Piko Study (1980). Figure 5.1 depicts the curve relating breadth to deadweight tonnage in that analysis. The first point to note is the large number of ships with a breadth of about 32 metres. The second point is that all ships with a breadth in excess of 32 metres lie above the regression line. That is, for ships with a capacity of more than about 85 000 dwt the regression equation consistently understates the breadth. The large number of ships designed to transit the Panama Canal is a likely cause for this bias.

A third point is that there are some Panamax-sized ships which are not designed with the Panama Canal limitation in mind. Examination of the data sample for this analysis showed that there were numerous ships in this category.



Source Piko (1980).

Figure 5.1 Breadth-deadweight tonnage relationship, 1977 data

The regression analysis in this study was split into three parts to allow for these observations, namely:

- Ships less than 50 000 dwt. The largest breadth recorded for any ship in this range was 32.31 metres which is just on the Panama Canal limit. Generally, the Panama Canal was not a constraint for ships in this category.
- Ships of 50 000 to 80 000 dwt but with a breadth less than or equal to 32.3 metres. Ships in this category are therefore able to transit the Panama Canal.
- Ships larger than 50 000 dwt but with a breadth greater than 32.3 metres. These ships were clearly designed without consideration of the limitations imposed by the Panama Canal. In the data sample only two ships with a deadweight capacity between 50 000 and 60 000 tonnes had a breadth in excess of 32.3 metres. Effectively, the range of the relationship is for ships from 60 000 to 255 000 dwt (the largest ship in the sample).

One exception to this classification was the regression equation developed for specific fuel consumption. It is unlikely that specific fuel consumption could be influenced by design constraints related to the Panama Canal. It could be argued that the installed power on a ship is also unlikely to be influenced by Panama Canal restrictions. However, it is possible that restrictions on hull dimensions might affect hull efficiency and, hence, power requirements. For this reason, it was decided to classify ships in the same three ways for estimating equations in which power was the dependent variable.

Equations were also developed for the full range of ship sizes so that comparisons could be made with the previous research results.

Results for length, breadth, draught and power models

Table 5.2 provides a comparison of the results of the Piko study analysis with equations of the same form developed from the data sample used in the present analysis. As in the previous analysis, the t-statistics in the present analysis are highly significant. In order to evaluate the two sets of estimated coefficients, the differences between the 1977 and 1986 estimates were compared with the larger of the two standard errors. In most cases, small differences in magnitude were associated with very small standard errors so that the difference exceeded plus-or-minus two standard errors. Such a result indicates that the observed difference may be greater than that which could be produced by chance. In three cases, the differences were less than plus-or-minus two standard errors, indicating that those differences could be attributed to chance variation. The three exceptions are the intercept terms and speed coefficients in the equation for engine power involving speed, and the tonnage coefficients in the breadth equations.

TABLE 5.2 COMPARISON OF EQUATIONS DERIVED FROM 1977 LLOYD'S DATA WITH EQUATIONS OF SAME FORM DERIVED FROM 1986 LLOYD'S DATA

Dependent variable	*Data source*	c_0	c_1	c_2	R^2
Length (metres)	1977	4.23 (695)	0.288 (162)	0	0.92
	1986	4.20 (869)	0.295 (214)	0	0.93
Breadth (metres)	1977	2.16 (340)	0.313 (169)	0	0.92
	1986	2.18 (419)	0.312 (211)	0	0.93
Draught (metres)	1977	1.43 (275)	0.275 (182)	0	0.93
	1986	1.38 (285)	0.285 (206)	0	0.93
Power (kilowatts)	1977	7.01 (243)	0.579 (68.9)	0	0.66
	1986	7.22 (385)	0.518 (97.1)	0	0.73
	1977	3.37 (19.0)	0.521 (63.3)	1.43 (20.7)	0.71
	1986	3.28 (30.0)	0.478 (103)	1.52 (36.4)	0.81

Notes
1. Equation form:
   $\ln$ (dependent variable) = $c_0 + c_1 \ln \text{DWT} + c_2 \ln \text{SPEED}$
2. SPEED measured in knots.
3. DWT measured in '000 tonnes.
4. t-statistics shown in parentheses.
5. ln = logarithms to the base e.

Sources Piko (1980). BTCE estimates.

Although most of the coefficients differ significantly in statistical terms, the differences are not large in absolute terms. Apart from the equations for power, the coefficients differ by less than 4 per cent. In addition, in each of the equations for length, breadth and draught, the intercept term and the tonnage coefficient move in opposite directions. The differences between the coefficients in the 1977 and 1986 equations for power tend to be greater than for the other equations.

This suggests that the estimates for length, breadth and draught based on the 1986 equations are unlikely to differ greatly from those based on the 1977 equations. Table 5.3 provides estimates from the two sets of equations for two ship sizes; the smaller ship of 65 000 dwt is in the Panamax range and the larger ship of 150 000 dwt is in the Cape size range. The differences in the estimates of the two sets of equations for length and draught are small. The differences in breadth estimates are in agreement with the observation that ships are tending to become wider. Table 5.3 also provides evidence that ships are becoming more efficient in that they require less power for a given size and speed.

The results in Table 5.3 provide some suggestion of the trend to broader and more efficient ships but the equations in Table 5.2 do not allow this trend to be investigated. The analysis was, therefore, extended by including age as an independent variable.

A further point detracting from the value of the equations in Table 5.2 is the constraint imposed by the Panama Canal. As discussed earlier, this was overcome by splitting the analysis into three ship size categories. Equations derived from this analysis are presented in Table 5.4.

The age coefficient is significant in all equations specified in Table 5.4 and has the expected sign. The equations indicate that newer ships are shorter, shallower and broader than older ships. Furthermore, the equations also confirm the trend that was suggested in Table 5.3, that newer ships require less power than older ships for a given deadweight capacity and speed. This age effect is most pronounced in the equations for installed power in the larger ships. The age coefficient is an order of magnitude larger in this equation than it is for the other equations. This suggests that efficiency of large ships has received considerable attention by ship designers. However, an alternative interpretation can be made. Older ships may have been originally designed for higher speeds than that at which they are now operated. If the speed recorded in Lloyd's Register of

TABLE 5.3 COMPARISON OF ESTIMATES OF SHIP CHARACTERISTICS DERIVED FROM THE EQUATIONS PRESENTED IN TABLE 5.2

Ship characteristics	*Vessel size ('000 dwt)*	*Regression equation derived from*	
		1977 data	*1986 data*
Length	65	229.0	228.0
(metres)	150	291.0	292.0
Breadth	65	32.0	32.5
(metres)	150	41.6	42.2
Draught	65	13.2	13.1
(metres)	150	16.6	16.6
Power[a]	65	12 400	11 900
(kilowatts)	150	20 150	18 300
Power[b]	65	11 850	11 600
(kilowatts)	150	18 450	17 350

a. Estimated from equation which does not include speed as an independent variable.
b. Estimated from equation which includes speed as an independent variable. A speed of 14.7 knots was assumed which is the average speed for ships included in the 1986 data sample.

Source BTCE estimates.

Ships is the current service speed, and if the power recorded is the original maximum continuous rating of the engine, then this would exaggerate the power required for the service speed recorded. If this interpretation is correct then the proportional reduction in power required indicated by the regression model implies a change in operating conditions as well as technological improvement.

Graphs illustrating the equations for length, breadth, draught and power listed in Table 5.4 are presented in Appendix VI. The graphs represent the relationships for ships of age 0 and 10 years. The effects of vessel age on length, breadth, draught and power are summarised in Figures 5.2 to 5.4.

Results for specific fuel consumption models

Fuel consumption for a ship of given size has decreased through two

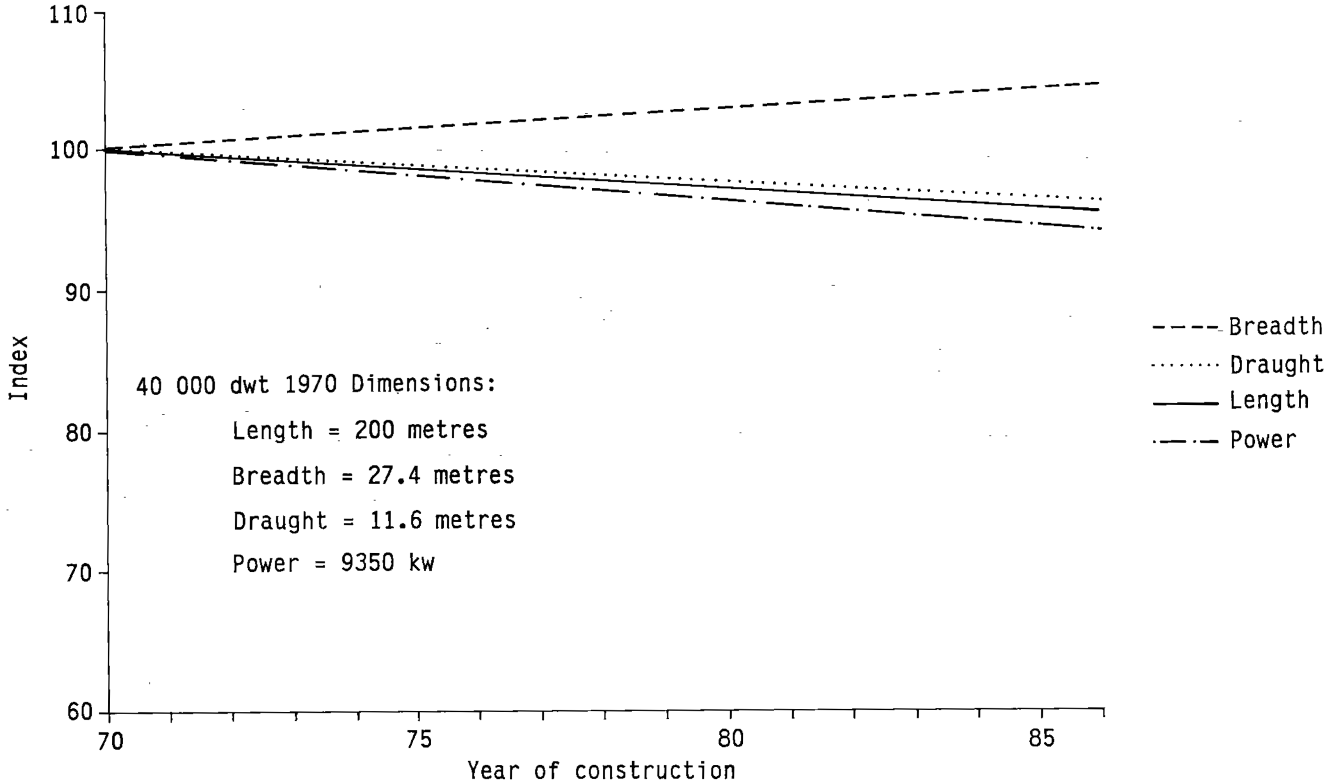
TABLE 5.4 EQUATIONS WHICH INCLUDE AGE AS AN INDEPENDENT VARIABLE DERIVED FROM 1986 LLOYD'S DATA

Dependent variable	*Size category*[a]	c_0	c_1	c_2	c_3	R^2
Length	1	4.131	0.3040	0.00287	0	0.88
(metres)		(548)	(139)	(20.0)		
	2	3.913	0.3611	0.00215	0	0.67
		(83.7)	(32.3)	(8.76)		
	3	4.374	0.2481	0.00209	0	0.79
		(93.4)	(26.4)	(4.0)		
Breadth	1	2.267	0.2951	-0.00288	0	0.86
(metres)		(2.78)	(125)	(-18.5)		
	2	3.036	0.1050	-0.00124	0	0.33
		(85.6)	(12.4)	(-6.70)		
	3	2.234	0.3141	-0.00305	0	0.86
		(41.7)	(29.2)	(-5.74)		
Draught	1	1.350	0.2874	0.00235	0	0.86
(metres)		(177)	(129)	(16.1)		
	2	1.068	0.3560	0.00127	0	0.60
		(19.9)	(27.7)	(4.49)		
	3	0.982	0.3675	0.00265	0	0.81
		(15.2)	(28.4)	(4.14)		
Power	1	3.369	0.5004	0.00371	1.439	0.72
(kilowatts)		(26.9)	(62.7)	(7.50)	(29.1)	
	2	4.073	0.5605	0.00881	1.061	0.41
		(13.2)	(12.3)	(8.67)	(11.5)	
	3	3.434	0.4985	0.02311	1.343	0.66
		(7.77)	(13.5)	(11.9)	(9.5)	
Specific fuel consumption	4	5.238	-0.02624	0.00750	0	0.13
(g/kw-h)		(3.01)	(-6.01)	(9.67)		

Notes
1. Equation form: ln (dep. variable) = $c_0 + c_1$ ln DWT + c_2 AGE + c_3 ln SPEED.
2. SPEED measured in knots.
3. DWT measured in '000 tonnes.
4. AGE measured in years relative to 1986.
5. t-statistics shown in parentheses.
6. ln = logarithms to the base e.

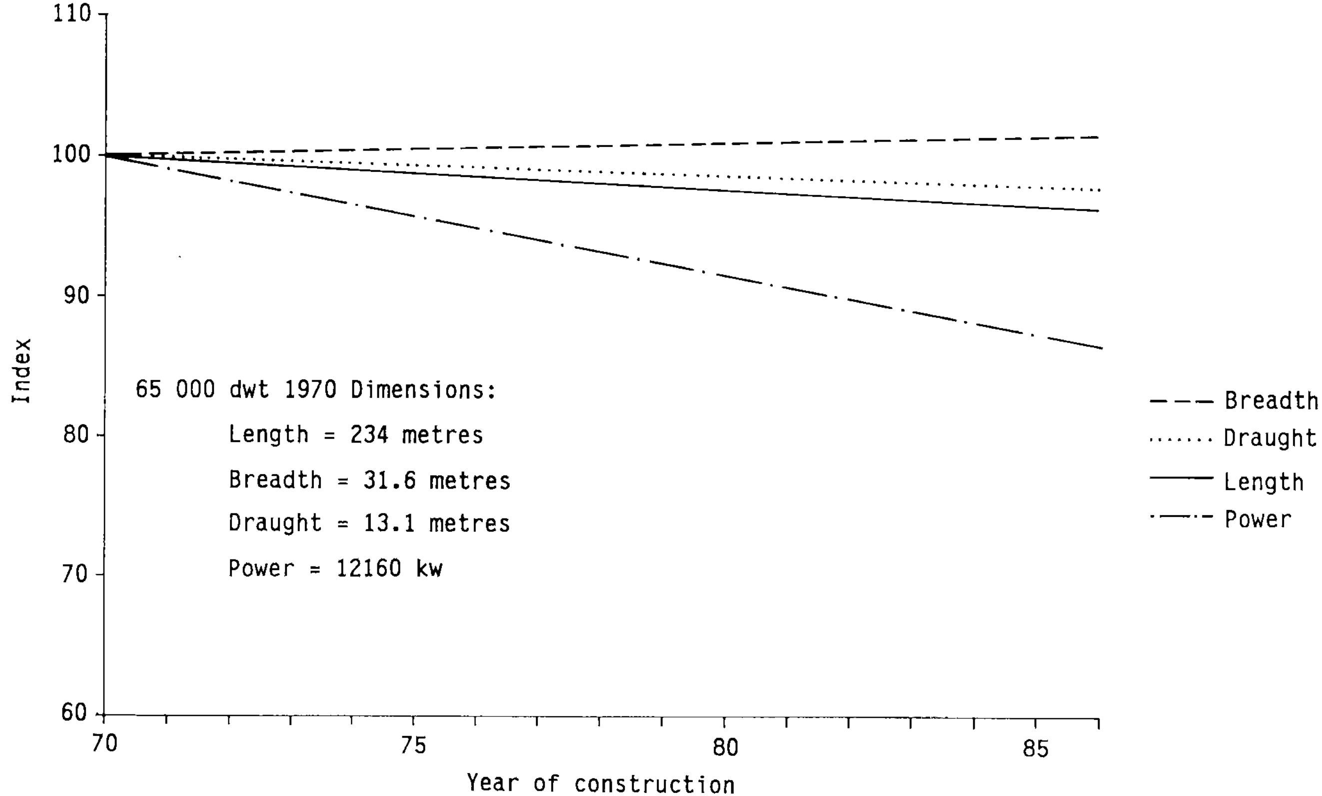
a. 1 = ships of less than 50 000 dwt.
2 = ships between 50 000 and 80 000 dwt with a breadth of less than or equal to 32.3 metres.
3 = ships greater than 50 000 dwt with a breadth greater than 32.3 metres.
4 = full data sample.

Source BTCE estimates.



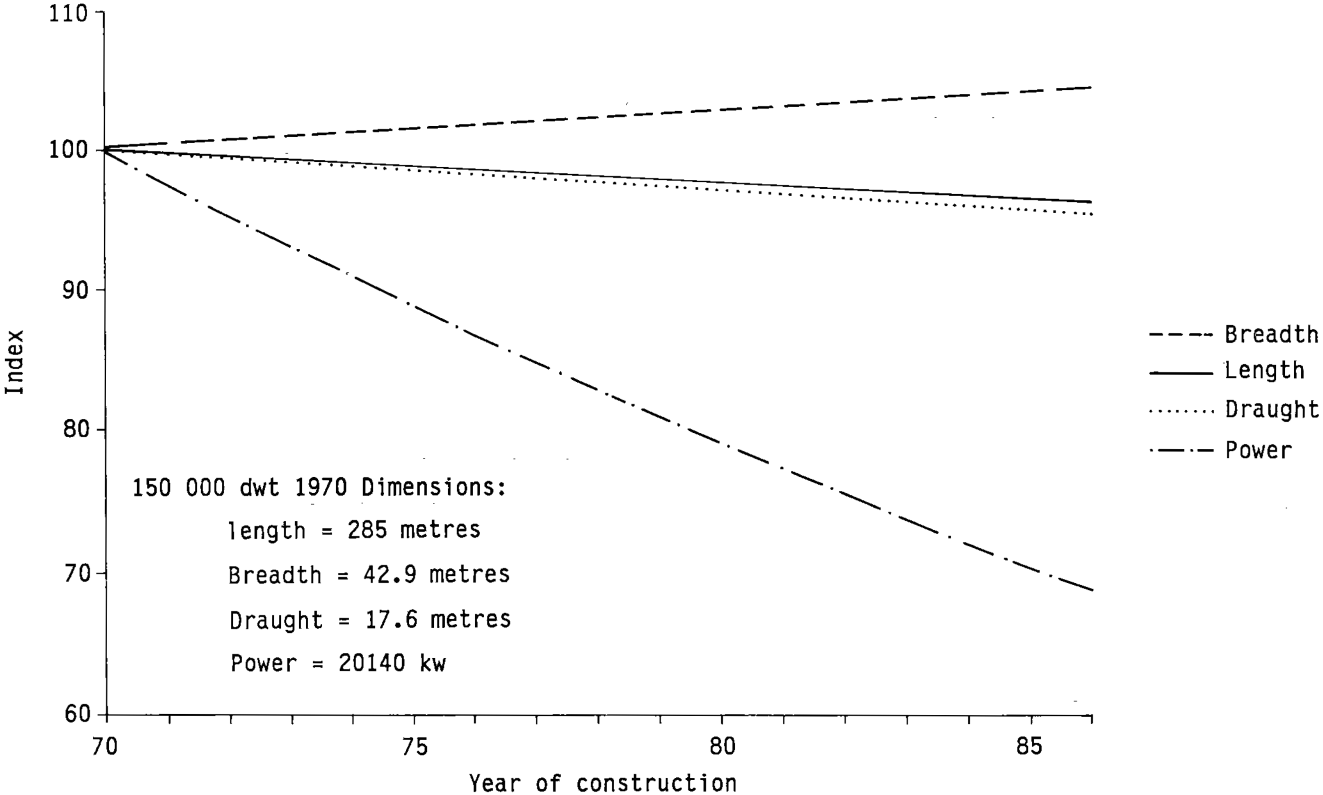
Source BTCE estimates.

Figure 5.2 Ship characteristics - year of construction relationships, Handymax vessels



Source BTCE estimates.

Figure 5.3 Ship characteristics - year of construction relationship, Panamax vessels



Source BTCE estimates.

Figure 5.4 Ship characteristics - year of construction relationship, Cape size vessels

mechanisms. The first involves better hull and propeller design together with better hull coatings. This has resulted in reduced power requirements. The second mechanism is in the design of more fuel efficient engines. This second mechanism is reflected in the final equation in Table 5.4. This equation for specific fuel consumption has significant coefficients with signs that are as expected. However, the equation explains only 13 per cent of the variation in the data.

An alternative approach was therefore adopted to estimate specific fuel consumption to overcome the poor explanatory power of the equation in Table 5.4. Instead of using data from Lloyd's Register, data on engine performance reported in industry journals were used, but only data for low speed engines were analysed as these engines are dominant in bulk ships. The engines chosen for the analysis were the larger models, thus the data generally represent the lowest specific fuel consumption for the analysis period. As for the previous analysis, only data from 1974 onwards were used.

Several models were estimated. The model which fits the data reasonably well, and was consistent with written opinions that opportunities for improvements to specific fuel consumption were becoming limited, is given in equation 5.1.

$$\ln SFC = \underset{(137.8)}{5.3906} - \underset{(-6.2610)}{0.11302} \ln T$$

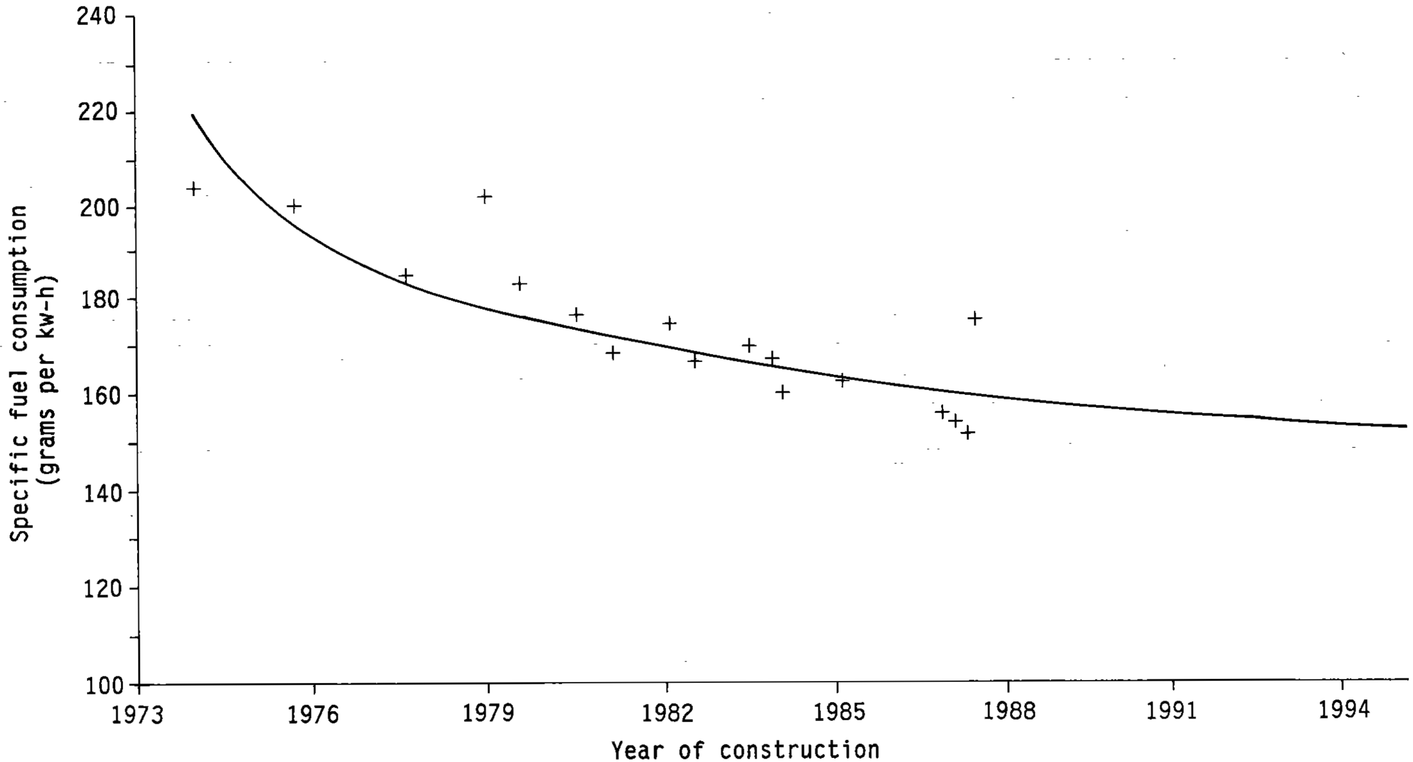
$R^2 = 0.74$ DW = 1.25

SFC = specific fuel consumption (g/kw-h)
T = time since 1973 (years)
ln = logarithms to the base e
t-statistics in brackets (5.1)

The coefficients are significant and the Durbin-Watson test for serial correlation is inconclusive. The equation, together with the data points, are illustrated in Figure 5.5.

The explanatory power of this equation is far superior to that derived from Lloyd's Register data. However, the equation does not include the effect of engine size. Engines used in this analysis are typically in the power range 10 000 kilowatts and above. In tonnage terms, this generally relates to ships greater than 70 000 dwt. Equation 5.1 is, therefore, appropriate for ships of this size. For smaller ships it is assumed that the tonnage coefficient derived in the analysis of Lloyd's Register is appropriate. This was done, resulting in equation 5.2 for ships smaller than 70 000 dwt.

$$\ln SFC = 5.5021 - 0.02624 \ln DWT - 0.11302 \ln T \qquad (5.2)$$



Source BTCE estimates.

Figure 5.5 Improvement in specific fuel consumption of low speed two-stroke marine diesel engines

Other results

Table 5.5 illustrates the effect of year of construction on the characteristics of ships of 65 000 and 150 000 dwt. The table illustrates the trends and the limitations imposed on the design of ships which must transit the Panama Canal. These ships have experienced only small changes in breadth, because of the obvious limitation imposed by the canal, and even smaller changes in draught. The major change in dimensions has been in length. This is also clearly illustrated in Figures 5.2 to 5.4.

Ships of Panamax size not designed for Panama Canal operation have shown significant increases in breadth and decreases in draught. In contrast, the reduction in length is less, but ships in this category tend to be marginally shorter than ships designed for the Panama Canal.

Table 5.5 also illustrates the much greater reduction in power requirements experienced by ships not constrained by the Panama Canal. The results suggest that power requirements for Panamax-sized ships are lower if they are not constrained by the Panama Canal. This may not be a correct interpretation, however, as the regression results may have been dominated by ships greater than Panamax size. This issue was not investigated; nevertheless, some caution should be exercised in estimating power requirements for ships in the Panamax range from these results.

Residual analysis

In Appendix VII, the theoretical assumptions underlying the residual distribution are examined, to give some indication of the predictive power of the estimated regression relationships. It is generally concluded that the most reliable equations estimated are those for length, breadth and draught.

FUTURE TRENDS

Ships are designed to comply with the constraints imposed on them by port facilities, channels and canals. Many ships are designed for specific trades so that the constraints are well defined. Others, generally smaller ships, are designed for more flexible operations but must also be designed to comply with a wide variety of port constraints. The trend towards wider ships was, for the most part, a means to use the largest ship possible in ports with restricted channel depth. Figures 5.2 to 5.4 clearly show this trade-off between breadth and draught. Shorter ships tend to be cheaper to construct than longer ships. This trend is also shown in Figures 5.2 to 5.4.

TABLE 5.5 COMPARISON OF ESTIMATES OF SHIP CHARACTERISTICS DERIVED FROM THE EQUATIONS PRESENTED IN TABLE 5.4.

Ship characteristics	*Year of construction*	*Ship size (dwt)*		
		65 000[a]	*65 000*[b]	*150 000*
Length (metres)	1976	231	228	281
	1981	228	226	278
	1986	226	224	275
Breadth (metres)	1976	31.9	33.6	43.7
	1981	32.1	34.1	44.4
	1986	32.3	34.7	45.1
Draught (metres)	1976	13.0	12.7	17.3
	1981	12.9	12.5	17.1
	1986	12.9	12.4	16.8
Power (kilowatts)	1976	11 500	11 600	17 500
	1981	11 000	10 300	15 600
	1986	10 600	9 200	13 900
Specific fuel consumption (g/kw-h)	1976	182	182	178
	1981	175	175	171
	1986	169	169	165

a. Ships constrained by Panama Canal, that is, breadth is less than or equal to 32.3 metres.
b. Ships not constrained by Panama Canal, that is, breadth is greater than 32.3 metres.

Source BTCE estimates.

Port restrictions will continue to influence the dimensions of ships. For example, the trade-off between breadth and other dimensions is limited by the width of channels and canals, and also by the distance shore-based loaders can reach over the ship. A further important consideration is that shorter, broader ships have a higher fuel consumption than longer, narrower ships of the same deadweight capacity. While the trend to wider ships is likely to continue, it is expected to be gradual as in the past.

The area where the most rapid change has occurred is in the operational efficiency of bulk ships. This has occurred on two fronts. The first approach has been to reduce specific fuel consumption, while the second has been to reduce the power requirements for a ship of a given size and service speed.

Reduction in specific fuel consumption

The opportunities for further reductions in specific fuel consumption are becoming more difficult to realise. 'It is generally accepted that engine designs have reached their development limit and that further raising of thermal efficiencies ... will depend on finding suitable materials which will be able to withstand the increased loads' (Motor Ship 1986c). There is a reasonable amount of development work in this area, such as in the use of ceramics in engines. Despite this there is generally thought to be 'much greater potential for further economy in ship hull form design, cleanliness of the wetted hull and proper smoothness and design, than in the main engine alone' (Schaar 1983).

Apart from improved materials to allow increased cylinder pressure, the major avenue for improved overall engine efficiency is in the use of exhaust gas turbines to maximise the use of waste heat in the exhaust (Motor Ship 1987c). Turbine equipment operating from exhaust gases can be used to drive electrical generators to supply the ships' electrical needs and also to provide propulsive power to the main shaft. The former purpose reduces fuel consumption for all purposes while the latter serves to improve the fuel efficiency of the propulsion system. However, as engines become more efficient, the opportunities for waste heat recovery become less.

Low speed, two-stroke diesels have dominated bulk ship designs because of their simplicity, reliability and low fuel consumption. Improvements in the design of four-stroke medium speed diesels may result in a greater use of these engines, especially if used in combination with exhaust gas turbines. The higher specific fuel consumption of medium speed diesels means that there is additional waste heat available for recovery. The use of exhaust gas turbines could mean that the overall efficiency of medium speed diesels may not be that much inferior to low speed two-stroke diesels. One forecast suggests that the difference is likely to be no more than 5 grams per kilowatt-hour after some unspecified time (Motor Ship 1984a). However, medium speed diesels suffer from the disadvantage that they tend to be less reliable than low speed two-stroke engines and hence incur higher maintenance costs.

Little is said in the literature on what levels future specific fuel consumption figures might reach. One approach is to extrapolate past trends using curves such as that shown in Figure 5.5. However, the value predicted for 1995, by Equation 5.1, of 154.7 is obviously too high. Specific fuel consumption rates of this magnitude had been reported for existing engines (Seatrade Business Review 1987a). Because the 1995 predicted value is outside the range of the data used for estimating the curve, the confidence intervals are wide. For 1995 the 90 per cent confidence interval extends from 138 to 174 grams per kilowatt-hour. A forecast value of specific fuel consumption in the range 145 to 150 grams per kilowatt-hour for 1995 for large low speed two-stroke marine engines appears reasonable.

Reduction in power requirements

There are many designs and devices which are claimed to have the potential for large fuel savings. Unfortunately, it is not clear for many of these claims as to what is being compared. Consequently, some claims of substantial reduction in power requirements should be treated cautiously.

The principal factor affecting power requirements is the shape of the hull. It is the stern that is currently receiving the greatest amount of attention. A ship recently completed in Britain illustrates the reduction in power requirements that can be achieved with current technology. The *Ironbridge* is a 173 000 dwt bulk carrier which was initially intended to be a duplicate of the bulk carrier *British Steel*. However, the aft end was redesigned to shift the rudder and skeg further aft, adding an extra 1.6 metres to the overall length of the ship. A prominent bulb was also incorporated which has the function of guiding the flow of water into the propeller which is 0.7 metres larger in diameter than the propeller on the *British Steel*. The larger propeller also rotates at the lower speed of 83 rpm compared to 97 rpm on the *British Steel*. Overall, the installed power was reduced from 14 600 kilowatts on the *British Steel* to 14 120 kilowatts on the *Ironbridge*; a reduction of 3 per cent. The trial speed of 13.4 knots is the same for both ships (Motor Ship 1987d).

An example of what can be done with hull shapes is the asymmetric stern which has been used mostly by West German yards. Asymmetric sterns have been used mostly on container ships but there appears to be no inherent reason why they could not also be used on bulk carriers. The idea behind the asymmetric stern is to guide the water flow into a pattern more consistent with the propeller's centre of pressure which moves to the side where the propeller blades move downwards. In practice, the first ship built with an asymmetric stern reported fuel savings of up to 8 per cent. Model tests are claimed to indicate savings of 5 to 9 per cent compared to hulls with symmetric sterns (Motor Ship 1984b).

Another hull modification involves the addition of thrusting fins attached horizontally on each side of the rudder horn to modify water flow through and beyond the propeller. These are claimed to reduce power requirements by 4 to 5 per cent (Motor Ship 1982).

The development of improved hull coatings has also led to reduced power requirements. These generally reduce the incidence of fouling under the water line and also act to keep the hull smooth. Self-polishing paints reduce the hull resistance compared to standard anti-fouling paints, but their main benefit is that the power requirements for a given speed remain constant for the life of the paint. Standard anti-fouling paints roughen with age and extra power is required to maintain the same speed. Cunard, for example, are reported as having found that grit blasting the hulls of seven vessels and recoating the hulls with self-polishing paint resulted in a reduced power requirement of 8 to 15 per cent (Seatrade Business Review 1987b).

Generally, the use of large diameter propellers rotating at low revolutions per minute is desirable for maximum efficiency. The maximum size of the propeller is limited by the draught of the ship and the design of the aft end of the hull. There is little expectation of significant increases in propeller diameter in the near future (Motor Ship 1987c).

The area of propeller design has also shown considerable possibilities for gains in efficiency. It has been claimed that many ships are not operating with the most efficient propeller and that efficiency gains of between 10 and 15 per cent could be achieved if more effective designs were chosen (Motor Ship 1985b). Potential gains available from some arrangements are (Motor Ship 1985b):

- Duct 6 to 12 per cent
- Prop/vane wheel 4 to 8 per cent
- Reaction fins 2 to 4 per cent.

High gains are claimed for various propeller designs. For example, an 18 per cent reduction in power requirements is claimed for a design called the 'high efficiency flow adapted' (HEFA) propeller (Motor Ship 1986b), and 23 per cent less power is claimed for the use of hollow propellers which would allow the fabrication of larger diameter propellers than currently used. The weight of solid propellers is said to be a limitation on their diameter (Motor Ship 1983).

Many of these approaches to improving ship efficiency have been available for many years. Their adoption depends on how shipowners perceive the trade-off between the additional capital costs involved and the reduced fuel costs likely to be achieved.

Taking these factors into account, it seems feasible that reduction in power requirements of 15 to 20 per cent should be possible in new ships by 1995. That this is achievable is supported by reports of the fuel consumption of the West German prototype 'Schiff der Zukunft' (SdZ) ships. These ships are claimed to have a fuel consumption of nearly 25 per cent less than a conventional vessel (Marine Propulsion International 1987c).

Wind assistance

Wind assistance is being investigated as a means of reducing fuel consumption. A 26 000 dwt ship, the *Usuki Pioneer*, which was the first ship to be designed with sail assistance in mind at the outset, went into service in December 1984. It is claimed that fuel savings of 15 to 40 per cent have been achieved compared to other fuel efficient ships. Other design characteristics of the ship, such as the design of the hull and arrangements for use of waste heat, may have contributed to this improvement in efficiency (Motor Ship 1985a).

Other sail assisted projects are either in progress or planned (Motor Ship 1986a), (Marine Propulsion International 1987a,b), (Conway 1985). However, sail assistance still appears to be at an early stage of development and is unlikely to be used in a large number of ships before the year 2000.

Self-unloading bulk ships

Self-unloading ships provide an excellent opportunity for improving ship productivity in some applications. They were developed originally for use in the Great Lakes in North America but are being increasingly used in ocean-going trades.

The concept of the self-unloader is basically simple. The most effective design uses gravity to feed conveyor belts located in tunnels in the bottom of the ship. The conveyor belts, in turn, feed loop elevators which bring the cargo to deck level. Conveyors along a boom discharge the cargo to the desired receiving point (Ocean Shipping Consultants 1986, 126). The loop elevators are usually installed at the end of the ship, but not always. The TNT *Alltrans* which trades on the Australian coast has a single elevator amidship. Unloading rates can be very high, with some ships operated by the Canadian Steamship Line (CSL) discharging cargo at the rate of 6000 tonnes per hour. Self-unloading systems, with a claimed capacity of over 10 000 tonnes per hour, are also available for installation in bulk carriers (Fairplay 1985). The high unloading rates allow fast turnaround times and lower in-port costs.

There are some disadvantages of self-unloading ships. The provision of self-unloading equipment can add a significant amount to the capital cost. Ocean Shipping Consultants (1986) estimate that the capital cost can be 18 to 25 per cent higher for self-unloaders compared to gearless ships of the same capacity. The actual premium depends very much on the newbuilding market and the equipment selected for the self-unloading ship. In the current depressed market, some yards have quoted prices not much higher than that for bulk ships without cargo-handling gear (Ocean Shipping Consultants 1986, 125). The space occupied by and the weight of the self-unloading equipment reduces the cargo capacity of the ship.

Operating costs are higher. The additional equipment requires additional maintenance and higher insurance and administration payments. On short-haul operations extra crew are often carried to operate the self unloading equipment. On longer voyages, stevedores are usually employed for this purpose (Ocean Shipping Consultants 1986, 131).

The economics of self-unloaders dictate that the more frequently the self-unloading equipment is used, the more likely the owner is to get a positive return on his investment. Self-unloaders are more likely to be successfully used on short-haul routes where there are more frequent opportunities to use the equipment. The Great Lakes, where self-unloaders originated, provide an environment where short-haul routes are the norm. However, in recent years they have been used increasingly on longer-haul ocean-going routes.

CSL currently use self-unloaders in the supply of coal to an electricity utility in Portugal. The coal is transhipped at Rotterdam from large conventional bulk ships. Smaller, self-unloading bulk ships then carry the coal to Portugal. The coal takes about a day to discharge at the Portugese port. The use of self-unloaders has involved the investment of US$5 million in port facilities but has allowed deferment of a comprehensive US$200 million development that would have been required if conventional bulk ships had been used (Motor Ship 1986d).

Iron ore deliveries to Bremen in West Germany have been improved through the use of self-unloaders. Previously, iron ore from Australia was delivered to Bremerhaven using Panamax vessels and carried by train from there to Bremen. Under the new arrangements the iron ore is carried to Rotterdam in ships of 100 000 to 150 000 dwt and self-unloaders carry it on to Bremen which has no cargo discharging equipment (Motor Ship 1986d).

Grain transport can benefit from the use of self-unloaders. Larger vessels can partially load in the port and then be topped up in deeper water using self-unloaders. Such a system would circumvent expensive channel dredging and reduce the need to top up at a second port. CSL are apparently offering topping-up services at a number of North American ports (Motor Ship 1986d). Similarly, self-unloaders can be used at draught restricted discharge ports to unload into shallow draught vessels or barges for final distribution to discharge points. China, for example, has taken delivery of two self-unloaders for the coastal transport of coal (SEA-Japan 1987). These ships will allow efficient operations in the absence of adequate port facilities.

Ocean Shipping Consultants (1986) analysed the costs of owning and operating self-unloading ships. Assuming a capital cost penalty of 20 per cent and stevedoring costs of 10 cents to 25 cents per tonne compared to $2 per tonne for conventional bulk ships, the break even voyage distance for self-unloaders was estimated. This was 3800 nautical miles for a 20 000 to 30 000 dwt ship and approximately 5000 nautical miles for ships of Panamax size and above. CSL also reported the results of a similar analysis. Under currently depressed market conditions CSL concluded that, if port investment and stevedoring costs are included in the analysis, self-unloaders will provide lower overall costs when compared with vessels with cargo-handling gear in trades up to 15 day cycles and up to 23 day cycles when compared with vessels with no cargo-handling gear.

Under 'normal' market conditions these cycle times increase to 35 and 40 days respectively. If port investment and stevedoring charges are not included, the break even cycle times become significantly shorter, dropping to 5 days for depressed conditions and 10 days for 'normal' market conditions (Motor Ship 1986d).

The best opportunities for the increased use of self-unloading ships appear to be those where they can be used to circumvent the limitations of draught and inadequate port facilities or where they will enable the use of larger vessels on long haul routes. While the Ocean Shipping Consultants' analysis assumes virtually no stevedoring charges, industrial relations issues may prevent the full benefit being achieved. The use of self-unloaders requires a full system analysis principally because their use implies the substitution of on-board equipment for shore-based equipment. Nevertheless, the flexibility of operation they offer is likely to ensure their greater use in the future.

SUMMARY

The analysis in this chapter indicates that dry bulk ships are becoming broader, shorter, shallower and more fuel efficient. Fuel efficiency has improved through two mechanisms. First, hull and propulsion system design advances have reduced power requirements, especially for large ships. Second, engine fuel efficiency has improved. These trends are expected to continue although fuel consumption advances are unlikely to continue at rates previously experienced.

Wind assistance has attracted some interest as a means of reducing fuel costs but is unlikely to be used extensively before the year 2000. Self-unloading bulk ships are finding an increasing number of applications. Their fast unloading rates and flexibility in operations will ensure an expanding role in bulk shipping.

CHAPTER 6 CREWING LEVELS

In recent years shipowners in the developed countries have become increasingly concerned about the higher ship operating costs they face, compared to those of ships operating under the flags of developing countries or flags of convenience. The expansion of these fleets has affected the competitiveness of the fleets of the traditional maritime countries. In fact, a major proportion of the cost differential can be attributed to the relatively high crew costs of the traditional maritime nations. Crew costs, although usually ranking behind capital and fuel costs in magnitude, are costs which are the most amenable to control by shipowners. It is for this reason that the traditional flag nations have examined the possibility of reducing crewing costs through crew size reductions. This chapter examines progress in crew size reductions and the ideas and technology used to bring them about.

THRESHOLDS IN THE REDUCTION OF CREWING LEVELS

Crewing levels can be reduced to two thresholds which are distinguishable mainly by the level of modern technology required to support them.

Initial threshold

The initial threshold is achievable by introducing some automated engine room functions to develop more efficient crew organisations. This generally takes the form of reducing the demarcation lines between deck and engine room classifications. The concept is known as horizontal linkage and has been adopted in several countries with the aim of developing interdepartmental functional flexibility. Under this concept, ratings' duties are broadened to allow them to be employed in either department. Ratings are referred to as General Purpose Crew (GPC) or Dual Purpose Crew (DPC). The interdepartmental flexibility system has been applied in most of the traditional maritime countries, where crew sizes have already been reduced to between 17 and 19, mainly by applying dual function ratings' duties. The concept also allows watch duties to be performed by either deck or engine officers. These officers are called Dual Purpose Officers (DPO) or General Purpose Officers (GPO) and are known as Watch Officers (WO) in Japan.

A second concept referred to as vertical linkage under which ratings in each department would carry out some officer's responsibilities, and vice versa, is being considered. This idea is yet to be clearly defined and has been adopted on an experimental basis only.

Lower threshold

The lower threshold can be achieved by introducing labour reducing technology for new ships at the design stage. The extent of the use of technology goes beyond that used in the initial threshold and involves increased automation of shipboard systems and operations, such as watchkeeping duties, cargo and engine systems, as well as the computerisation of communications, management and administration, and also the development of low maintenance machinery which effectively transfers most repair and maintenance activities to onshore (Winther 1987). Current maintenance planning systems which require historical records are replaced in this threshold by vibration analysis and other data logging techniques, to predict future maintenance requirements of the machinery and to plan its undertaking at an optimum time and place (Marine Propulsion International 1987d).

Technology and approaches that can be and have been adopted in this lower threshold are as follows:

- Watchkeeping functions concerned with ship position, machinery status and performance, hazards and passage planning, are now being facilitated by integrated electronic systems, designed to provide more accurate and better presented information to the watchkeeping officer. Computers, combined with radar and various navigation aids, can facilitate automatic plotting of position and automatic chart display, as well as assessment of possible options. These systems can be integrated through data links to machinery and administration computer data banks to enable effective control of fuel usage and to give a passage planning facility. The centralised bridge will be the point where all information and controls of the ship's functions will be located.
- The centralised bridge system also requires a rationalisation of officers' responsibilities, so that fewer officers with broader qualifications will be required to analyse and respond to the information presented on the centralised bridge (Loynes 1983). In the longer term, Holder (1983) suggests the possibility of a periodically unmanned navigational bridge should not be ruled out.

- Machinery activities have been automated to the extent where unattended machinery spaces have been the norm for several years. These allow for rationalisation of engineering duties and reduction in onboard maintenance and repair tasks. In the longer term, new process design will aim at the development of devices with increased reliability and minimum maintenance requirements onboard, with many of the maintenance tasks subcontracted to shipyards. In an example given by Moreby (1983), a Swedish Shipping Company, Brostroms, reduced their off-hire time from 15 to 5 days per annum, by subcontracting the main engine maintenance of their deep sea ships to Japanese yards.

- Combined automatic systems for deck and cargo are considered uneconomic at present, as the functions are split between the bridge, the cargo control and the machinery control centres. Automation is a long-term objective and depends on the earlier establishment of other major control centres and the type of cargo handled. Cargo handling automation must be a safe operation and this will come with the development of reliable sensors and with the display of relevant information at a central location. The same can be said of automation and remote control of mooring and berthing. In the short-term, the problem is solved by using special off-ship crews that join the ship only for mooring and berthing activities.

- Satellite systems such as Satcom will link ship and shore computers. The Future Global Maritime Distress and Safety System (FGMDSS), which is designed to serve as a basis for search and rescue and which was expected to be integrated with satellite communications and be operational by 1990, would allow for the elimination of traditional radio operator duties (Brown 1986). However, recent delays in satellite launch programs may delay the establishment of these systems. Ship and shore computer links will improve exchange of, and access to, information and will lead to manning reductions in Head Office as well as onboard, as more management responsibilities will be transferred to ship and some administration activities computerised.

- Transfer of authority from the Head Office to ship is expected to facilitate management and administration improvement. The enhanced communication and computer systems will allow the ship crew to be less dependent on Head Office for effective management of the ship in both operational and financial terms.

The measures listed in Appendix VIII, are lower threshold techniques aimed at achieving further improvements to onboard efficiency leading to feasible crew reductions to the level of 12 or lower. As a consequence of crew reductions, the ratio of ratings to officers has fallen from over 2:1 to 1:1 in ships with crew levels of around 18 and in ships of the future the ratio could fall to 1:2 or even 1:3 (Moreby 1983). It appears inevitable that below a certain crew level (probably 15) some jobs traditionally performed by ratings will be transferred to shore or accomplished by officers. Thus, the traditional distinct divisions between officers' and ratings' duties will become blurred, undermining the traditional perceptions of shipboard organisation.

APPROACHES ADOPTED BY SELECTED COUNTRIES IN ACHIEVING CREWING LEVEL REDUCTIONS

The reduction of crewing levels to the initial threshold through re-organisation of ship departmental functions and with only small changes to engineering systems, is already well advanced in many countries. Table 6.1 indicates current typical crewing levels on new ships in several representative countries. Generally, the changes in operations' procedures have necessitated crews to be re-educated and retrained. The introduction of new technology and upgrading of ship specifications would raise the initial cost of the ship, although this is generally considered minor in the achievement of the initial threshold.

TABLE 6.1 CREWING LEVELS FOR NEW SHIPS IN SERVICE IN SELECTED COUNTRIES, DECEMBER 1986

Country	*Complement*
Australia	26
Japan	18
United States of America	21
Norway	18
Denmark	17
Federal Republic of Germany	18
Netherlands	19
United Kingdom	18
Flags of convenience	31-33
International Transport Workers' Federation	25-27

Sources Australian Maritime Industry Mission (1985). Bergstrand (1983, 60-62). Lloyd's Ship Manager (1983a).

Although crewing levels shown in Table 6.1 have been achieved through only a small investment in new technology, they have only been attained after wide consultations and with the co-operation of governments, shipowners, unions and other interested parties. In view of the extensive consultations involved, it is not surprising that a variety of approaches have been used in reducing crew complements below 20. Approaches adopted in some countries are summarised in the following paragraphs.

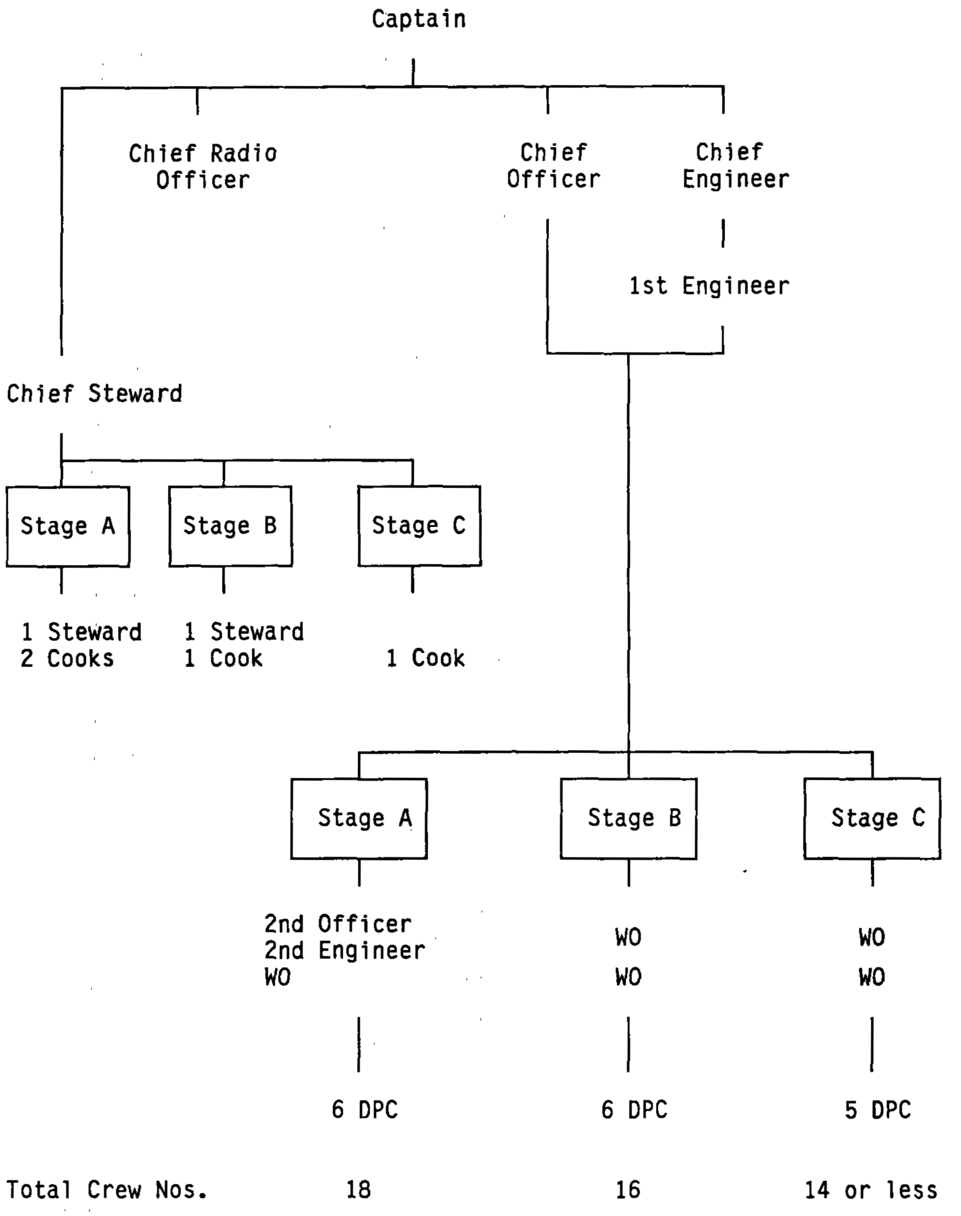
Japan

In Japan, a long-term modernisation program has been established (Figure 6.1) and is well advanced in its realisation. The program commenced in 1979 with six ships, known as M-zero ships, to carry out integrated experiments, including horizontally linked work arrangements. M-zero ships typically had periodically unmanned engine rooms (Wada 1986, 5-7).

After successful completion of the basic stage, further modernisation was extended to what the Japanese shipowners refer to as the Stage A experiment. At this stage, the conventional distinction between deck and engine departments was removed with the introduction of six DPC ratings. The WO system was applied to the positions of Third Officer and Third Engineer. A total complement of 18 was achieved by providing a suitable education and training program for dual purpose seafarers. The reduced crewing level of 18 has now been institutionalised in the relevant laws (Wada 1986, 8).

The next step, the Stage B experiment, commenced in 1982 with one ship and then expanded to 15 vessels in 1986. The main change in crewing in Stage B was to replace the Second Officer and Second Engineer with a single WO. Catering staff numbers were also reduced by one. This resulted in a reduction of the crew complement to 16 (Wada 1986, 9-10).

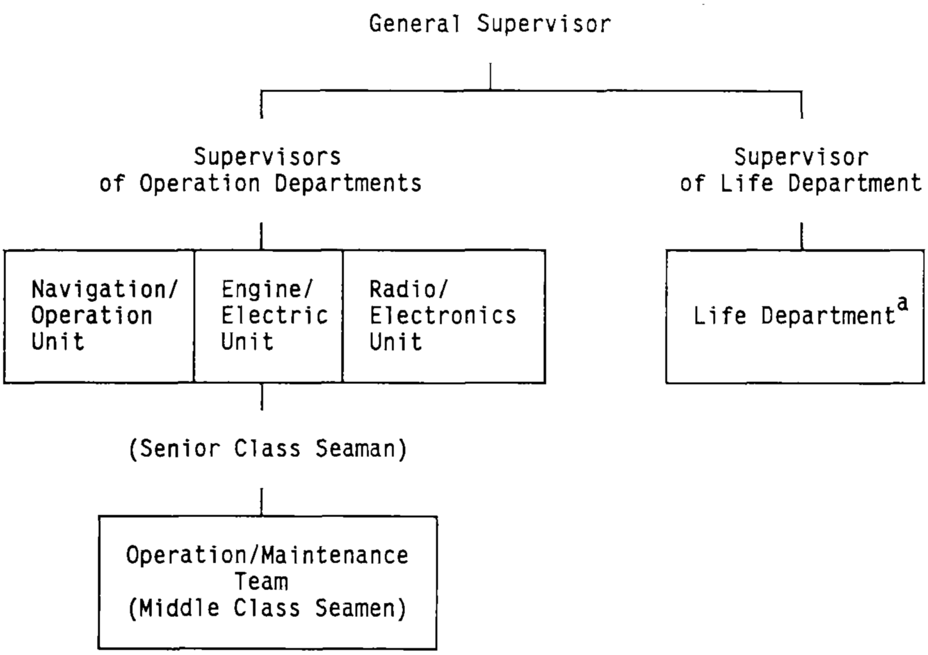
In Stage C it is planned to reduce the crew numbers further. After all transition stages, the duties of the chief officers and chief engineers will be reconsidered with the intention of their replacement by WO officers performing dual functions. It is likely that the radio department's work will be added to that of the multi-function officer staff. This has already been instituted on experimental ships of Norway and the Federal Republic of Germany (FRG) (Fairplay Pacific 1986). Also, the conventional role of the captain is expected to change. In particular, the captain is expected to be referred to as a general supervisor, a position corresponding to the present captain but with a revised workload. A comprehensive study will be undertaken by the Research Committee on the Modernisation of Manning Systems to



Source Wada (1986).

Figure 6.1 Transition stages to crew complements of 14 or less

determine a way of distributing onboard work such as administration and watch duties. The final structure of the crew organisation is shown in Figure 6.2 (Wada 1986, 15-24).



a. Covers catering, personnel matters and financial management.

Source Wada (1986).

Figure 6.2 Final hypothetical organisation of ship complement

Changes in crewing levels have been integrated with an introduction of technological innovations and development of sophisticated systems on ships and onshore. Depending on company choice, technological progress and distribution of workload, shipowners are not constrained to move progressively through stages A, B and C. On new well-equipped ships aiming at less than 16 crew, some transition stages can be combined (for example, Stages M-zero + A or Stages A + B), so that they can quickly achieve lower crewing levels (Figure 6.1) (Wada 1986, 22-24). From Autumn 1987, some owners are expected to have deployed ships with crews of less than 12 on container vessels and car carriers which seem to be the best candidates for the sophisticated technology required (Seatrade Week 1987).

United States of America

In the USA, a reduction in crew size to 21 has been achieved for a series of diesel powered vessels commissioned in 1984-85. This level seems to be a minimum and has been achieved by the following rationalisations:

- periodically unmanned engine rooms;
- reduction of catering staff and services to the crew; and
- introduction of common dining facilities.

These are typical of the initial threshold technical improvements, but the horizontal linkages in crew organisation used in Japan and other countries have not been adopted. The traditional departmental crew structure is maintained without any crewing level flexibility expected (Australian Maritime Industry Mission 1985).

Norway

In Norway, ships generally operate with a crew of 18, but there are some exceptions (for example, 16 on the new *'Probo Biakh'* vessel). There are still separate facilities for deck and engine officers, but the positions of able seaman (AB) and motorman have been combined into that of ship mechanic. Ship mechanics (all new entrants) are required to perform bridge watchkeeping functions. Future reduced crewing level options are being examined, with consideration being given to the inclusion of the Japanese WO concept, one-man bridge, maintenance strategies and cargo handling control (Australian Maritime Industry Mission 1985). A trial of one-man bridge operation was recently completed on a 77 800 dwt product tanker. It was reported as being successful, releasing three subordinates from watchkeeping duties (Winther 1987).

Denmark

In Denmark, as from 1986, a new position of Ship's Assistant has been created which is a combined deck and engine room rating. There are no plans to introduce dual or multi-functional officers. Future crewing level reductions are believed to be achievable by adopting modern technology (Australian Maritime Industry Mission 1985).

Federal Republic of Germany

Like Norway, the FRG has adopted the concept of the ship mechanic. Future German crew sizes will vary depending on trades and maintenance workload required. Some vessels will use shore-based facilities for maintenance purposes with little maintenance onboard and, therefore, reduced crew requirements. There is no proposal for officers performing dual duties currently under consideration (Australian Maritime Industry Mission 1985) and changes to the radio officer category depend on new administrative regulations (Marine Propulsion International 1987c). The one-man watch operation has also been successfully tried on two prototype Schiff der Zukunft (SdZ) ships, that is, Ship of the Future, which are capable of operating with a 12-man crew. Six more have been ordered (Winther 1987).

Netherlands

In the Netherlands, 19-man crews have been adopted following successfully completed experiments that proved the practicality of new crew categories of Semi-integrated Officer and integrated General Purpose rating. These officers are qualified to the top level in one discipline and to the basic watchkeeping level in the other. There is no need for a senior officer fully qualified in both functions. The new rating certificate requires three years' training at a nautical school and one year's sea training in the engine and deck departments (Australian Maritime Industry Mission 1985).

United Kingdom

In the UK, minimum crewing levels for new bulk carriers have been defined as 18. Existing ships often employ crews of 30 or more. There is no government policy on crewing levels, except for minimum levels for safety purposes, with these issues being left to individual companies.

Many shipowners have adopted the alternative strategy of flagging out their ships. In 1980, the UK had more than 27 million gross tons on its register; at the end of 1985, that had fallen to 14.3 million tons (The Economist 1986). Not all of the tonnage that departed the UK register, however, did so to reduce crew costs only. Half of those ships had been owned by foreigners, previously attracted by investment grants and a favourable exchange rate (British Maritime Charitable Foundation 1986). Those shipowners who have transferred to Far Eastern registers, such as Hong Kong or Singapore, and who have employed cheap crews from underdeveloped countries (for example, India or the Phillipines) in combination with British officers, have been able to reduce total crew costs without reducing crew levels or increasing capital expenditure. This has been a very common shipowner practice in the UK (Bergstrand 1983, 68-69).

Other British shipowners have adopted a policy of reducing crew levels. For example, one British shipping company, the Blue Star, competing against Scandinavian and other European companies which have flagged out and operate ships employing low cost Third World crews, has been active in the development of a long-term crew reduction program. It began with a level of 33 (UK flag crew levels for bulk carriers range between 25 and 35), reduced it to 25 by using GPC and reorganising work schedules, reduced it further to 17 by 'designing out' high workload areas (mainly by incorporating an automatic engineroom, although Blue Star ruled out any high degree of sophistication in automation) and postulated further reductions to an interim 15 and an eventual 12. Blue Star anticipates it will be about five years before crewing levels of 12 can be widely adopted. Table 6.2 indicates the progression of crewing levels planned by Blue Star (Lloyd's Ship Manager 1984d).

Technical design features of low crew ships operated by Blue Star include centralised ship control stations, extensive use of satellite communications between ship and shore, streamlining of onboard documentation and paperwork, and increasing application of shipboard computers for maintenance management, administration, stock control, fuel economy and other management systems.

The UK Department of Trade has allocated £6 million to fund a program to develop an efficient ship over four years (Winther 1987). Known as the Efficient Ship Programme, the scheme has been underway for three years. The UK Department of Trade has indicated that it is looking to industry support for the Programme after the first stage of four years is completed. On present planning, the first ship to be equipped with the technology developed during the Programme, is expected to be available in 1990.

TABLE 6.2 FROM A CREW OF 33 TO 12 FOR BLUE STAR'S BULK CARRIERS

	Original specification	*Feasible specification*	*Lower threshold specifications*	
Engine Room	Chief Engineer Second Engineer Third Engineer Fourth Engineer Electrician Store Keeper Three Donkeymen Two Day-workers	Chief Engineer Second Engineer Third Engineer Electrician/Engineer Day-worker (GPC)	Chief Engineer Second Engineer Third Engineer Engineroom Hand/ Fitter (GPC)	Chief Engineer Second Engineer Third Engineer
Hotel	Chief Steward Cook Assistant Cook Four Stewards	Cook/Chief Steward Two Stewards	Cook/Chief Steward Two Stewards	Cook/Chief Steward Steward

TABLE 6.2 (Cont.) FROM A CREW OF 33 TO 12 FOR BLUE STAR'S BULK CARRIERS

	Original specification	*Feasible specification*	*Lower threshold specifications*	
Deck	Captain Mate Second Mate Third Mate Radio Officer Bosun Nine ABs	Captain Mate Second Mate Third Mate Bosun (GPC) Three ABs (GPC) Radio Officer	Captain Mate Second Mate Third Mate Three ABs (GPC) Radio Officer/ Electronics Engineer	Captain Mate Second Mate Three ABs (GPC) Radio Officer/ Electronics Engineer
Crew numbers	33	17	15	12

Source Lloyd's Ship Manager (1984d).

Australia

In Australia, the reduction in crewing levels commenced in earnest as an outcome of the Crawford Report (Department of Transport 1981). This report concluded that Australian shipowners were disadvantaged compared to their competitors by high crew costs and a restrictive taxation regime which increased their capital costs.

The Commonwealth Government accepted the recommendations of the report, and liberalised depreciation allowances and extended the investment allowance to new ships in overseas trades, whereas previously these benefits had been available only to ships exclusively engaged in domestic trading. However, the investment allowance was subsequently abolished for all industries. The depreciation allowance continued on the condition that ships were crewed in accordance with a crewing certificate issued by the DTC. This approach was successful in achieving a crewing level of 26, down from the previous level of 32, for new ships.

The level of 26 has been applied to BHP's three modern bulk carriers - *Iron Kembla* and *Iron Newcastle* of 147 000 dwt and the *Iron Pacific* of 231 000 dwt. The traditional crew structure is still retained on these ships which serve both the coastal and international trades.

Crewing levels were scrutinised by government, business and labour representatives, when a maritime mission visited several countries in 1985 to examine modern shipboard practices (Australian Maritime Industry Mission 1985). An outcome of the mission was the establishment of the Maritime Industry Development Committee (MIDC) in January 1986. The MIDC was tasked to develop methods for implementing more economic crewing of Australian ships. In October 1986, the MIDC recommended a complement of 21 crew for the next generation of ships flying the Australian flag (Maritime Industry Development Committee 1986). The MIDC recommendations envisage new training and retraining programs leading to qualified integrated ratings (equivalent to DPC) and a review of officer training to ensure it is closely related to the introduction of modern technology. The Commonwealth Government has accepted the major recommendations, and legislation, the *Ships (Capital Grants) Act 1987* which links taxation concessions with a reduction of crew levels to 21, was recently passed by the Commonwealth Parliament. The first ship built under these arrangements was the *Portland*, designed to carry alumina from Western Australia to Portland.

International Transport Workers' Federation

The ITF has expressed the opinion that crewing levels should be determined in the context of the level of the reserve (unemployed seamen) and of the total number of hours worked. ITF examined annual hours worked in the European Economic Community (EEC) countries and estimated that the average number of overtime hours per week onboard ship for the six maritime countries of the EEC was almost 30, compared with normal work time of 40 hours onshore. Taking into account the excessive overtime hours and safety issues, ITF determined a minimum crewing level of 25 to 27 for ships larger than 6000 gross registered tonnes (Lloyd's Ship Manager 1983a).

The ITF minimum level was, however, based on a traditional crewing concept, without taking into account the introduction of new technology and GPC leading to reduced crewing scales in developed countries. The lack of training of seamen in some of the less developed countries would influence the opportunity to introduce GPC in FOC vessels.

FUTURE CREWING TRENDS

The current severe maritime recession, combined with the growth of low operating cost competition, whether under FOC or State-owned national flags, has adversely affected shipowners in traditional maritime states. The bulk shipping market has shown no signs of recovering from the recession for several years. For example, the Nippon Yusen Kaisha (NYK) Research Chamber (1985), in its analysis of the balance between supply and demand in bulk shipping, expects surplus tonnage to increase to 26 per cent of tonnage available to the market by 1988. Even under NYK's most optimistic assumptions, the proportional gap between supply and demand is unlikely, before 1988, to decline from 1984 levels. Shipowners will need to pay close attention to costs if they are to survive the recession. Among the major cost items, crew levels represent the best opportunity for controlling or reducing costs. Two approaches have been adopted. One approach is to flag out, taking advantage of lower cost crews available through open or quasi-open registries. The second approach discussed in this chapter is to adopt more advanced technology to reduce crewing levels.

Introduction of advanced technology to achieve a reduction in crew sizes to around 12, is only feasible on new ships. It can be expected that, initially, only a few ships will operate with crewing levels of this size, so that the new systems and the new crew organisations can be tested in practice. In the-long term, maritime nations will be aiming at more efficient ships with fuel-efficient engines and reduced crewing levels.

New shipboard technology has encouraged reduction in crew numbers and structural changes in crew organisation. In view of current trends, it is expected that crewing scales for new ships will be in the range of 10 to 12 crewmen by the year 1990, in some advanced maritime countries. Some countries have already reduced crewing levels significantly. Norway has ships with 13-man crews and Taiwan plans 12-man crews shortly (Seatrade Week 1987). Hitachi's Computer Automated Vessel proposal is an example of possible future minimum crewing levels, aiming at a crew of eight but initially starting with a crew of 11 or 12. Another Japanese shipping company, Mitsubishi Heavy Industries Ltd, designed a highly rationalised ship for a crew of five (Table 6.3) (Australian Maritime Industry Mission 1985). A crew of 12, plus four maintenance staff onshore, has already been adopted on the Swedish Orient Line Roll-on Roll-off service to the Mediterranean (Brown 1986).

The technology is available to substantially reduce crew sizes. While this technology is potentially very reliable, the economic feasibility of small crew sizes must also be demonstrated. The reduction in crew sizes is essentially a trade-off between increased capital costs and reduced crew costs. As crew sizes become smaller, the trade-off becomes less attractive. At some stage, the increased capital costs required to achieve further reductions will more than offset the crew cost reductions attained. It is not clear at what crew size the trade-off becomes uneconomic; however, given the present state of technology and crew costs, it appears that, at crew sizes of 12, further reductions may not be justified. Nevertheless, the trend of reducing crewing levels is irreversible and will become a reality on many modern ships.

SUMMARY

Shipowners in developed countries are seeking to reduce crew costs so that they may remain competitive. One way of doing this is to introduce labour saving technology into their ships so that manning levels may be reduced. Two thresholds can be identified in this process. The first stage requires only a minor introduction of new technology, generally in the form of allowing enginerooms to be unmanned for extended periods. Concurrently with this, crew organisations are modified to remove the distinction between deck and engineroom classifications. Crew sizes can be reduced to between 17 and 19 at this stage. Many advanced maritime countries commonly have ships with manning levels in this range. Australian shipowners have also taken this approach and reduced manning levels in new ships to 26 in 1986 and more recently to 21.

TABLE 6.3 RATIONALISED SHIP BY MITSUBISHI HEAVY INDUSTRIES LTD.

Rationalised ship	*18 crew*	*12 crew*	*9 crew*	*5 crew*
Complement	1 Captain 3 Officers 1 Chief Engineer 3 Engineers 1 Radio Officer 6 GPC 3 Cooks	1 Captain 1 Chief Officer 1 Chief Engineer 1 Radio Officer 5 WOs 1 DPC 2 Cooks	1 Captain 7 WOs 1 Cook	1 Captain 3 WOs 1 Cook
Bridge and navigation				
Collision avoidance	Automatic Radar Plotting Aid (ARPA)	)Integrated navigation)system (weather)routing, Global)Positioning System)(GPS))		
Anti-grounding			Integrated ship control system (all systems centralised in the bridge)	Cockpit bridge
Navigation planning	Satellite navigation			
Position fixing				Ship control from shore station

TABLE 6.3 (Cont.) RATIONALISED SHIP BY MITSUBISHI HEAVY INDUSTRIES LTD.

Rationalised ship	*18 crew*	*12 crew*	*9 crew*	*5 crew*
Communication	Satellite communication	Satellite (data link)		
	Closed circuit TV			
Logging	Dual installation	Navigation recorder		
Deck and cargo handling				
Mooring	Auto-tension winch	One-man operated mooring gears	Position keeping	Shore facilities
Berth and anchoring	Remote winch control		Centralised remote control	
Ballasting	Remote ballast control	Automatic ballasting control		
Cargo handling	Loading computer	Hatch cover remote open/close	Operation guidance system of cargo handling	Automatic cargo handling
	Remote reading tank-level, pressure and temperature	Hull stress monitoring On-line loading computer	Cleaning equipment of cargo hold	

TABLE 6.3 (Cont.) RATIONALISED SHIP BY MITSUBISHI HEAVY INDUSTRIES LTD.

Rationalised ship	*18 crew*	*12 crew*	*9 crew*	*5 crew*
Engine room and machine control				
Automation and instrumentation	Standby sequence control	Easy operation		Fully automated and optimum control
High reliability	Condition monitoring Micro computer aided machinery control	Easy maintenance Condition diagnosis	Highly reliable equipment	
Fire fighting	Automatic fire extinguisher	Power management	Operation guidance system	
Spare gear and maintenance	Spare gear management system (onboard)	Spare gear and maintenance management from shore base		Monitoring from shore station

TABLE 6.3 (Cont.) RATIONALISED SHIP BY MITSUBISHI HEAVY INDUSTRIES LTD.

Rationalised ship	*18 crew*	*12 crew*	*9 crew*	*5 crew*
Accommodation and others				
Accommodation	Lift		Accommodation cleaning system	Simplified accommodation
Galley	Rationalised galley	Automatic cooking machine	Ready made food	
Fire fighting	Accommodation fire detector	Highly reliable fire detection and fire fighting	Automatic fire extinguishing	
Store, fuel oil, water	Hoist/crane	Bunkering monitor and remote control	Bunkering automation	

Source Australian Maritime Industry Mission (1985).

The second stage requires a much more extensive use of modern technology involving a greater use of automation and computer and communication techniques. Crew sizes of 12 to 14 are now used on an experimental basis but are expected to be common on new ships in the early 1990s.

There is a tradeoff between increased capital costs and reduced crew costs. Data were not available to allow estimation of what level of technology and crew sizes would achieve minimum operating costs but it is thought to be at around a crew size of 12 for current crew costs and prices of technology.

CHAPTER 7 CREW COSTS

Chapters 7, 8 and 9 deal with crew, capital and other bulk ship operating cost components, respectively. Chapter 9 brings these components together to form a complete operating cost model.

CREW COST DETERMINANTS

To compare crew costs between countries and between ship operators within a country is a difficult task, given not only the scarce and often contradictory information, but also the complexity of crew cost components. For commercial reasons, shipowners are generally reluctant to provide information on operating costs - in particular, crew costs - therefore limiting data sources available to researchers. Nevertheless, in spite of the data being scarce and fragmentary, compilation of crew cost information has been based on three determinants in this study. They are crewing levels, crew nationality and conditions of service.

Crewing levels

Crewing levels assumed are those prescribed in Chapter 6 for new ships. These levels depend, first, on statutory requirements of the government of the country of registry or ITF's minimum limits for FOC ships. Second, they depend upon agreements between owners and unions, as well as the owner's own crewing policy.

Crew nationality

The nationality of the crew in some countries depends on statutory requirements. The requirements can be restrictive, with some governments insisting that crews be nationals of that country while others, such as FOC registries, have no nationality requirements. Where there are no statutory requirements, there are more options open to the shipowner who, by mixing nationalities, may reduce costs. The options are as follows (Bergstrand 1983, 64-65):

- a nationally registered ship crewed by nationals at national wage levels;

- a nationally registered ship crewed by foreign seamen at national wage levels;
- a nationally registered ship crewed by foreign seamen at less than national wage levels;
- an open registry ship crewed by seamen at ITF wage levels;
- an open registry ship crewed by seamen at non-ITF wage levels;
- an open registry ship crewed by seamen at their own national wage levels; or
- a nationally registered ship crewed by a mixture of national and foreign seamen employed at differentiated wage levels.

The possibility of employing foreign seamen at wage levels less than those of nationals can be attractive for a shipowner wishing to reduce labour costs. The extent to which this practice is permitted varies between countries. For example, Denmark, the FRG, and the UK require only the Senior Officer's position to be filled by nationals. The variation in costs with nationality for a UK registered ship is illustrated in Table 7.1.

In practice, legal requirements are often not strictly enforced, either as a result of agreements with unions or because of practical difficulties. For example, there were special provisions which allowed Norwegian ships trading in the Far East to employ Asian crews in contrast to the normal practice that required the Master and 67 per cent of crew to be nationals (Bergstrand 1983, 67). Recently, Norway has opened an International Ship Register, whereby shipowners can employ foreign seamen. It should be understood that the exploitation-of-labour argument does not apply when shipowners employ relatively cheap foreign seafarers. Because seafarers bear no living expenses onboard ship and because such seafarers evaluate their incomes in terms of purchasing power within their own countries, it cannot be argued that they are being exploited by shipowners who pay nationals a higher wage than the foreign seafarers receive. Where legal requirements do not allow shipowners to take advantage of cheaper crews, such shipowners can switch, and often do, to an open registry. Chapter 2 provides more detail on open registries and the extent of flag switching.

Conditions of service

The conditions of service such as basic wage rates, leave, overtime, bonuses, allowances and victualling are generally dependent upon shipowners, ship and voyage type. Usually, service conditions are set by agreements between governments, unions and owners.

TABLE 7.1 TOTAL CREW COSTS FOR A UK REGISTERED 25 000 DWT TANKER, 1985

Crew composition	*per year*	*Index*
UK officers and ratings (including pensions, benefits and social security payments)	780 000	1.00
Singapore officers, Filipino ratings	570 000	0.73
UK officers and ratings (offshore agreement - management company A)	545 000	0.70
UK officers and ratings (offshore agreement - management company B)	479 000	0.61
European officers (5), Filipino other officers and ratings	455 000	0.58
Indian officers and ratings (company C)	426 000	0.55
UK officers and ratings (offshore agreement - management company D)	423 000	0.54
Indian officers and ratings (company E)	404 000	0.52

Source International Transport Workers' Federation (1985).

Employment on a continuous basis or for a contractual period (for example, 1 year), rather than for a voyage only, is the norm in many traditional maritime countries. Engagement for a single voyage is commonly used by FOC shipping, as well as some nationally registered (for example, Greek) shipping, and is usually arranged by world-wide crewing agencies (Lloyd's Ship Manager 1983c). Standard ITF conditions include a 9 months' period of employment, but conditions agreed to between the shipowner and the crewing agent may not comply with ITF requirements (Lloyd's Ship Manager 1983a). The single voyage system of employment can bring cost savings to shipowners and can increase the net pay for the crew through a reduction in 'social' costs (taxes, social security contributions, union dues). Increased wages for seamen through the single voyage system of employment are offset by the prospect of discontinuity of employment, an insecure future, unfamiliarity with the ship's features and the shipowner's policy, and limited career progression. Seamen generally benefit more by staying with the same employer for longer periods.

EARNINGS COMPONENTS

The treatment of earnings is valid only if all components of seamen's remuneration are taken into account. These components include not only basic wages and salaries but also the impact of working hours, overtime and leave entitlements, as well as on-costs incurred by the shipowner. In comparing crew costs, it is convenient to calculate all components of seamen's earnings, leave and any other entitlements on an annual basis.

Tables 7.2 and 7.3 illustrate the different pay components that can apply when a general cargo ship is manned by crews of different nationalities.

Even when pay components are common, their application is seldom the same. A typical example of this is the seniority system. While some shipowners count seniority from the moment the employee commenced employment as a seafarer for the very first time, others take into account only the period since joining the company. In Japan, those seamen who transfer employment between shipping companies are only granted a proportion of their previous seniority (Australian Maritime Industry Mission 1985). Also, many material benefits of employment come in forms other than cash, that is, fringe benefits. These are extremely difficult to quantify and compare.

Owners are primarily concerned with the total cost of crewing their vessels, while seafarers are concerned with their net earnings. Several European maritime countries offer special tax allowances to seamen which can greatly improve their net earnings (Lloyd's Ship Manager 1984b) at no cost to the shipowner. For example, Norwegian seamen can claim against tax a US$101 monthly expenses allowance, while Greek ratings pay no tax at all. Danish seamen enjoy a fixed monthly expenses allowance of US$71, and if they go deep sea, they are entitled to a further monthly allowance of US$108. No special tax allowances are available to Australian seamen.

Comparison of direct pay components

Table 7.4 illustrates the differences in basic wages between Australia, Japan and the ITF minimum wage scale for able seamen. The table also illustrates the effect the different application of allowances can have on total direct payments to seamen.

Comparing only direct pay components (social security costs, and so on excluded), Japanese able seamen enjoy the highest earnings of the countries selected for comparison, both in total and per hour worked.

TABLE 7.2 PAY COMPONENTS FOR A TYPICAL UK GENERAL CARGO SHIP, CREWED BY UK OFFICERS AND INDIAN RATINGS

UK officers	*Indian ratings*
Salary including	Basic wage
basic pay	Leave and subsistence pay
leave pay	Overtime
subsistence allowance	Bonus
overtime allowance	Overseas supplement
Productivity payments	National holidays
Limitation of hours payments	Retention allowance
Extra service supplementary payments	Shipkeeping allowance
Nights onboard allowance	Provident fund
Weekend work in port payments	Welfare fund (ITF/ISF funding)
Merchant Navy Officers Pension Fund contributions	Special work allowance
Company pension fund contributions	

Source Adapted from Downard (1982).

TABLE 7.3 PAY COMPONENTS FOR A TYPICAL KOREAN GENERAL CARGO SHIP, CREWED BY KOREAN OFFICERS AND RATINGS

Basic wage
Onboard allowance
Overtime allowance
Annual bonus
Annual vacation allowance
Vacation meal allowance
Retirement allowance
Special extra work allowance

Note If Korean crew are not company employees, there are compensatory payments for termination of service before the end of the agreed period, if the termination is through no fault of the crew member.

Source Downard (1982).

TABLE 7.4 COMPARISON OF ABLE SEAMAN'S MONTHLY WAGES AND OTHER COMPONENTS FOR AUSTRALIA, JAPAN AND ITF, 1986[a]

Pay component	*Australia*	*Japan*	*ITF (Far East)*
Basic wages (US$)	1 307	1 160	739
Overtime (US$)	0	377	656
Holiday overtime (US$)	0	203	630
Yearly bonuses (US$)	0	532	0
Daily navigation (US$)	0	318	0
Other allowances (US$)	0	868	0
Total (US$)	1 307	3 458	2 025
Number of seamen to fill one berth[b]	1.926	1.323	1.099
Total (US$)	2 517	4 575	2 225
Hours worked	243	217	256
Hourly total rate (US$)	10.358	21.083	8.691
Ratio of total cost per berth to the basic wage	1.926	3.944	3.011

a. Exchange rates as at 2 September, 1986.
b. Calculated assuming leave entitlements of 338, 118 and 36 days after one year's service for Australia, Japan and ITF (Far East), respectively. The 118 days leave entitlement for Japanese seamen is composed of 90 days (including 25 days of paid leave) to be taken as shore leave and 28 days of onboard non-working holidays.

Sources Lloyd's Shipping Economist (1986). Personal communication with Embassy of Japan. BTCE estimates.

It should be noted that the Australian seamen have a consolidated wage based on a 56-hour week, which includes overtime and other allowances. Leave is accrued at the rate of 0.926 days for each day the seafarer is on articles which compensates for weekends, annual leave, public holidays, and so on. However, despite the high number of seamen required to fill a berth, the inclusion of overtime and allowances in a consolidated wage results in a lower ratio of total cost per berth to the basic wage. This ratio indicates the invalidity of basing international comparisons on basic wage rates alone, as has been done in other studies.

Social security costs

One advantage of FOC registrations for shipowners is the avoidance of highly institutionalised social security costs. Using flexible arrangements, a seafarer may also avoid social security, pension and other benefit contributions that are compulsory in his homeland. For example, he can choose to pay 'voluntary' contributions in order to retain entitlements to retirement pensions, health services, and so on (Goss 1985). If a shipowner saves on contributions to social security funds, he can offer to highly skilled seamen increased net wages to attract them, yet still retain significant cost reductions.

Social security costs, thought previously to be of assistance to shipowners in attracting and keeping skilled seafarers, have become increasingly expensive. For example, in Sweden they amount to 75 per cent of basic wages (Moreby 1985). With the oversupply of cheap crews from Comecon countries (for example, China) and from developing countries (for example, Philippines), high social security costs translate into a relatively heavy burden on the operators in traditional maritime countries, making it difficult for them to compete effectively in the very depressed world shipping market.

None of these social security payments represent costs in the economic sense of the term, that is, as payments for real goods and services priced at levels which approximate marginal social costs. On the contrary, they all represent transfer payments and do not necessarily imply any social cost whatsoever (Goss 1985). Although other industries within the same country are bearing the same burdens, most would not be facing international competition to the same extent as the shipping industry.

Exchange rates

The depreciation of a nation's currency relative to competitors' currencies is an important, if not the most important, factor in giving a competitive edge to shipowners and shippers of that nation. For example, the Australia dollar's rapid depreciation in the mid-1980s has been the single most important factor for many years, in raising Australia's international competitiveness, both for Australian exporters as well as shipping. As this example shows, a system of floating exchange rates can quickly complicate any international comparisons of crew costs, because currencies can appreciate or depreciate relative to one another within a short period of time.

A currency which is appreciating relative to the US dollar, results in increasing wages to seafarers and costs to owners in US dollar terms; a depreciating currency results in decreasing wages and costs in US dollars. Another example concerns the Japanese yen strengthening sharply against the US dollar during 1986. This boosted a Japanese seaman's basic wages per month from US$821 in 1985 to US$1160 in 1986 (Lloyd's Shipping Economist 1986), an increase of 41 per cent, despite the fact that only a 3.14 per cent award increase in Japanese yen was accepted in 1986 (Lloyd's Ship Manager 1986c). In this chapter, exchange rates as at 2 September 1986 were used for the basic analysis. At this time, the Australian dollar was at a low value against the US dollar and the Japanese yen. This results, therefore, in relatively lower Australian crew costs, which would be higher if exchange rates for another date were chosen. The sensitivity of the results to exchange rate variability was tested by re-computing the results using exchange rates for 2 June 1987 (see Table 7.6).

MULTIPLIER APPROACH TO ESTIMATING CREW COSTS

An interesting method of calculating total crew costs by a quick rule-of-thumb technique has been suggested by Moreby (1985). Basic annual wages of an able seaman in each country, when multiplied by a certain factor, gives the total cost of filling a berth for a full calendar year. This factor is intended to take account of all components of direct and indirect labour costs plus shore-based personnel administration costs. Training costs are excluded from the equation, as difficulties are encountered in establishing precisely who pays for training. If the 1982 multipliers can be applied to 1986 conditions, then the current annual costs of filling a berth can be estimated by this technique; the results of this process are shown in Table 7.5. However, the use of 1982 multipliers to calculate 1986 crew costs is almost certainly invalid because:

- the composition of 1986 crew costs for most countries has changed substantially from that which applied in 1982; and
- changes in crew structures have occurred through crew reduction programs, which have lowered the ratio of ratings to officers.

For these reasons, it was decided not to adopt this approach for the main cost estimates derived in this chapter; but for comparative purposes, estimates using this multiplier approach have been made. Other techniques exist, but have not been applied here as alternatives to the Moreby (1985) technique and the BTCE approach (which is set out in the following paragraphs).

TABLE 7.5 ESTIMATED TOTAL 1986 ANNUAL CREW COSTS IN SELECTED COUNTRIES, USING MOREBY'S 1982 MULTIPLIERS

Country	*Able seaman's monthly wages (1) (US$)*	*Moreby's multiplier (2)*	*Annual cost per berth (3)=(1)x(2)x12 (US$)*	*Crew complement per ship (4)*	*Total costs per ship (5)=(3)x(4) (US$)*	*Index (6)*
Japan	1160	13.2	183 744	18	3 307 000	9.3
USA	1488	5.6	99 994	21	2 100 000	5.9
Norway	849	8.0	81 504	18	1 467 000	4.1
UK	581	6.8	47 410	18	853 000	2.4
ITF (Far East)	739	3.0	26 604	27	718 000	2.0
FOC	300	3.0	10 800	33	356 000	1.0

Sources Lloyd's Shipping Economist (1986). Moreby (1985).

BTCE CREW COST ESTIMATES

Notwithstanding the problems associated with computing and comparing separate crew cost components, annual crew costs per berth to shipowners, including all direct and indirect components, have been estimated and are summarised in Table 7.6 for selected countries. The BTCE used separate earnings components wherever they were available, in particular for the Australian and Japanese costs. For all other countries, published gross figures were used, with adjustments being made for missing components where these could be identified. The estimates set out in Table 7.6 are considerably different from those derived by the alternative approach of Moreby (1985).

TABLE 7.6 ESTIMATED TOTAL ANNUAL CREW COSTS PER BERTH IN SELECTED COUNTRIES, 1986 AND 1987

	Crew cost per berth		*Indexes*	
Country	*(US$)*[a]	*(US$)*[b]	*a*	*b*
Australia	56 000	66 000	1.0	1.0
Japan	87 400	93 500	1.6	1.4
USA	145 000	145 000	2.6	2.2
FRG	57 000	64 000	1.0	1.0
Norway	64 000	69 000	1.1	1.0
UK	33 000-50 000	36 000-55 000	0.9	0.8
ITF	22 000-33 000	24 000-36 000	0.6	0.5
FOC	15 000	15 000	0.3	0.2

a. Exchange rates as at 2 September 1986
US$1 = $A1.6543
= Yen 154.15
= Deutschmark 2.0285
= Norwegian Krone 7.197
= Pounds Sterling 0.6714
= Philippines peso 19.709.

b. Exchange rates as at 2 June 1987
US$1 = $A1.408
= Yen 144.13
= Deutschmark 1.820
= Norwegian Krone 6.719
= Pounds Sterling 0.6116
= Philippines peso 20.085.

Sources Financial Review (1986). Financial Review (1987). BTCE estimates.

The assumptions used in compiling Table 7.6 and results achieved are summarised in the following points:

- Australian cost estimates assumed a 26-man crew at a berth cost of $A93 000. The Bureau of Transport Economics (1985) computed an annual average variable cost per berth of $A91 000 for a bulk carrier on the basis of data obtained for 20 bulk carriers. The total berth cost is comprised of the following components:

  - Salaries and wages, less a deduction for keep, constituted 71 per cent of total costs and included payroll tax, leave entitlement of 0.926 days for every day worked, study leave, overtime allowance, stand-by allowance, short-term money and pay in lieu of notice.

  - Superannuation, long service leave, levies and calls are assumed to be about 9 per cent of total costs.

  - Joining and leaving costs can range from 1 to 7 per cent of total costs, varying among companies depending on whether first class or economy class air fares for officers and ratings apply: 4 per cent on average is assumed.

  - Crew-related Protection and Indemnity (P and I) club contributions paid by the ship operators varies widely too. The average contribution is estimated at $A7 000 per berth. It is not common to include P and I club contributions as a crew cost, but as the International Labour Office (1986) in its labour cost comparison accounted for all costs incurred by the employer, including premiums for casualty insurance, life insurance and similar insurance schemes, P and I club contributions have been included here.

  - P and I club write-offs are assumed to be 1 per cent of total costs; they represent the claim excess borne by the shipping companies.

  - Victualling costs covering all food aboard ship plus cartage are assumed to be 5 per cent of total costs.

  - Cabin stores are assumed to be 1 per cent of total costs.

  - Sundries include laundry costs, videos, Mercantile Marine Office fees and crew requests. Assumed to be less than 0.5 per cent, they are ignored.

  The 1985 estimated total cost per berth was increased to $A93 000 to account for the national wage increase of 2.4 per cent in 1986. This amount is comparable on a per berth basis to traditional maritime country standards. In fact, the costs are similar to those of European flag vessels but are significantly higher than open registry or some Asian flag ships.

- Costs for operating Western German ships based on information made available to the Australian Maritime Industry Mission and from Lloyd's publications. The Australian Maritime Industry Mission (1985) quoted annual German costs per berth as DM130 000 for an officer's berth and from DM70 000 to DM80 000 for the berth of a ship's mechanic. For an 18-crew complement consisting of nine officers and nine ratings, the average cost per berth is DM100 000 to DM105 000. Tinsley (1986) quoted costs of DM2.32 million for a Panamax bulk carrier with a 24-man crew, or DM97 000 per berth. However, in Chapter 6 it is noted that the reduction of crew sizes to fewer than 20 usually requires a more highly trained crew and, therefore, higher pay per crew member. In this analysis it is assumed that the crew receive 10 per cent of the wages saved through reductions in crew numbers. When this adjustment is made, the cost per berth increases to DM100 000. It is believed that Lloyd's Ship Manager estimates do not include P and I premiums. Typical P and I premiums for a German crew member on a container ship are US$5000 (pers. comm. 1987) or, after allowing for leave entitlements, US$7200 per berth. Using the 2 September 1986 exchange rate, total cost per berth can range from US$57 000 to US$60 000. The lower cost was used in the comparison (Table 7.6) as P and I premiums are assumed to be lower for bulk ships.

- Norwegian costs for a seafarer are based on an average estimate of US$46 000, quoted by Lloyd's Ship Manager (1986b). This estimate is converted into a cost per berth, using the typical Norwegian crew work schedule of 6 months' work and 3 months' leave.

- UK costs are based on information provided in publications of Lloyd's and the International Transport Workers' Federation. The ITF (1985) presented crew costs for different nationality compositions. For example, if British crews of 21 were employed, the cost per berth would amount to US$55 000 for tankers and US$50 000 for bulk ships. However, where Indian, Hong Kong or other Asian ratings were employed, UK owners would enjoy cheaper crew costs per berth, but at the expense of a larger complement.

- Costs for Japan are derived from examples of wages provided to the Australian Maritime Industry Mission (1985) and the 1985 Agreement between owners and the All Japanese Seamen's Union (Table 7.7). As the application of awards differs between companies and depends on company choice and earnings, several assumptions were necessary for the allowances and on-costs to allow estimation of seamen's earnings and the shipowners' costs. Details of these allowances are given in Appendix IX.

TABLE 7.7 JAPANESE ANNUAL CREW COST FOR AN 18-CREW COMPLEMENT, 1985
('000 yen)

Cost component	*Cost*
Basic salaries and wages	47 800
Overtime plus allowances (Appendix IX)	76 730
	124 530
Annual leave provision (37 days)	12 755
Consolidated wages	137 285
Ten per cent of basic for other allowances and bonuses	4 780
Ten per cent of basic for standby duties, outfitting and other onshore duties	4 780
Productivity improvement (calculated as 10 per cent of savings on crew costs achieved by reducing crew size from 25 to 18)	1 860
Fifteen per cent of consolidated wages for other wage-related costs, such as recruitment, travel and accommodation, clothing and medical expenses	20 590
Victualling	7 000
Protection and Indemnity Insurance	14 400
Thirty per cent of consolidated wages for social security and retirement schemes.	41 200
	231 895
'Reserve' (four seamen on basic wages)	10 600
Total annual cost for 18-crew	242 495
Cost per berth (242 945/18)	13 470
or as at 2 September 1986 exchange rates[a]	US$87 400

a. 154.15 yen equals US$1.

Sources Financial Review (1986). BTCE estimates.

- The Japanese system is based on life-time employment and each company retains financial responsibility for its unemployed seamen. In Lloyd's List (1987), the Japanese Shipowner's Association was quoted to have claimed that as many as 10 000 seafarers were surplus and that more than 70 per cent of the deep-sea fleet of 600 ships may be trading unprofitably.
- The estimates of crew costs in this analysis are based on a Japanese surplus of 7300, which was the number reported to the Australian Maritime Industry Mission (1985). This figure represents 22 per cent of the total number of active seamen; thus for an 18-crew complement, the cost of four additional men was included to take account of the shipowners' responsibility for paying the reserve crew. This lower surplus estimate of 7300 is based on two arguments. First, it represents the average minimum number of seamen in 1986. Second, the rationalisation of the Japanese shipping industry aimed at improving competitiveness and the reduction of excessive numbers of seafarers is under way (Embassy of Japan pers. comm. 1987).
- Some of the surplus crewmen are employed in productive shore-based work and those that are unemployed, receive lower pay than active seamen. While little information is available on the pay levels of surplus seamen, it is understood that such remuneration is considerably less than that paid to active seamen, possibly only the basic wage. Shipowners have also been able to secure employment in other industries for some of the surplus seafarers.
- Lloyd's Shipping Economist (1981) estimated Japanese costs per crew member and included very high additional costs for surplus seamen. The estimated costs at the beginning of 1980 were much higher than those calculated for the FRG, France or UK and amounted to US$84 640 for an officer and US$71 000 for a rating. For comparative purposes, these costs were converted into Japanese yen and then into a per berth cost for the 18-crew complement, and finally updated to 1986 levels by factoring in subsequent award increases quoted by Lloyd's Ship Manager (1981, 1982, 1983b, 1984c, 1985, 1986c). The resultant cost per berth in 1986, estimated by this method, is US$185 700. This cost level, if correct, would rank Japan as the highest crew cost country in the world. However, as with the example of the multipliers estimated by Moreby (1985), such a process ignores other changes that may have occurred during the intervening years, such as the application of allowances.

- ITF rates are those set in 1983 for World-wide and Far East (85 per cent of World-wide) FOC ships. They have not been increased since. The ITF decision to hold the rates constant was justified by the difficult situation of the shipping industry (Lloyd's List 1986b). Another organisation, the International Labour Organisation (ILO), approved a very low mimimum basic rate for ABs in developing countries of US$360 per month, including $80 for overtime. This rate was set in view of the high unemployment level and inflation rate (Lloyd's Ship Manager 1986c).
- It was also reported to ITF that China has offered full crews for as low as US$260 000 per vessel per annum, compared with ITF approved agreements of US$750 000 and ILO, US$500 000. Clearly, the rates for Chinese crew are very low; for example, a master would earn US$93 per month, an able seaman US$29 per month. Even though ITF rates are low, it is also believed that 'double book keeping' has taken place, whereby crews are supposed to be paid ITF rates, but are in fact paid substantially less (Lloyd's List 1986a).

INTERNATIONAL COMPARISON OF TOTAL CREWING COSTS

Table 7.8 combines the crewing levels shown in Table 6.1 and the cost per berth shown in Table 7.6 to derive a total crew cost per ship. The estimated Australian total crew costs are less than the Japanese total, although the assumed Australian crewing level of 26 is higher than the Japanese complement of 18. The difference is even greater, if the cost of filling a berth is applied to the lower level of 21 for new Australian flag vessels, recently agreed to following the MIDC (1986) recommendations. An Australian ship with a crew of 21 would have a total crew cost of US$1 203 000.

The cost of crewing a ship based on ITF pay rates applicable to Far East seamen is 13 and 27 per cent less than the estimated total crew costs for FRG and Norwegian vessels, respectively. FOC crews consisting of European officers and Filipino ratings cost less than half of the FRG or Norwegian crews. Clearly, significant savings in crew costs are available to those shipowners who transfer to an open registry.

INTERNATIONAL COMPARISON WITH MANUFACTURING INDUSTRY LABOUR COSTS

The ratio of crew costs per berth with labour costs in manufacturing industry was estimated for selected countries. The comparison presented in Table 7.9 shows that most developed countries have ratios of around 3:1. This indicates that, while international comparisons

TABLE 7.8 ESTIMATED TOTAL ANNUAL CREW COSTS IN SELECTED COUNTRIES, 1986

Country	*Crew cost per berth (US$)*	*Crew per ship*	*Total costs per ship (US$)*	*Index*
Australia	56 000	26	1 456 000	1.0
Japan	87 400	18	1 573 000	1.1
USA	145 000	21	3 045 000	2.1
FRG	57 000	18	1 026 000	0.7
Norway	64 000	18	1 152 000	0.8
UK	50 000	18	900 000	0.6
ITF	33 000	27	891 000	0.6
FOC[a]	15 000	33	495 000	0.3

a. European Officers, Filipino ratings.

Source BTCE estimates.

of crew costs per berth give a wide variation in costs, generally labour costs for seamen are reasonably consistent with labour costs in other industries for most industrialised countries. The ratio of around 3:1 reflects the seven days per week operation of ships, onboard working hours and leave entitlement differences between shipping and manufacturing. While 1985 average working hours per day in manufacturing in industrial countries varied from 8.5 hours in Japan to 6.1 hours in Norway (International Labour Office 1986b), a seaman remains onboard for 24 hours per day and generally works more overtime, than land based employees. Onboard overtime was estimated by ITF to be 6 hours per working day for European countries (Chapter 6) and 8 hours per working day for Japan (Australian Maritime Industry Mission 1985). The increased overtime hours are reflected in higher wages, whereas the long absences from home are reflected in increased leave entitlements.

The high US ratio relates to relatively generous seamen's wages and conditions, as well as high social security and other on-costs. The low FRG ratio implies a high level of labour costs for all industries, and, particularly, high social security costs. The high Philippines' ratio is more indicative of generally low wages in manufacturing industries, than of high wages for seamen.

TABLE 7.9 COMPARISON OF CREW COSTS PER BERTH WITH MANUFACTURING INDUSTRY LABOUR COSTS OR EMPLOYEE COMPENSATION, 1986

Cost[a]	*Country*	*Crew cost per berth*[b] *US$*	*Labour costs or compensation*[b] *US$*	*Ratio*
LC	Australia	56 000	18 000	3.1
CR	Japan	87 400	29 560	3.0
CR	USA	145 000	29 200	5.0
LC	FRG	57 000	35 220	1.6
LC	Norway	64 000	22 920	2.8
LC	UK	50 000	16 011	3.1
CR	FOC	15 000	1 234	12.2

a. The concepts of 'labour costs' (LC) or 'compensation of employee' (CR) generally include direct wages, bonuses and gratuities, plus on-costs incurred by the employer. More precise definitions may be found in the 1985 Year Book of Labour Statistics (ILO 1986a).
b. Exchange rate as at 2 September 1986.

Sources International Labour Office (1986a), updated by using Lloyd's wage index and Far Eastern Review indexes. BTCE estimates.

FUTURE TRENDS IN CREW COSTS

The cost of labour will remain one of the main determinants of the competitiveness and profitability of ships in the late 1980s. While total comparative crew costs will be affected by some exogenous factors, such as inflation and fluctuating exchange rates, crewing level reductions and resulting industrial relations issues will have the major impact on the future level of crew costs.

However, continuation of the decline in employment opportunities, stemming from crew rationalisation and other factors, has resulted in national seamen's unions and the ITF being more concerned with employment preservation than with higher pay settlements. The ITF has not yet adjusted its 1983 pay scale (Lloyd's Ship Manager 1986a) and has agreed to the application of even lower wages by some countries which are facing high unemployment, for example, the Philippines (Lloyd's Ship Manager 1986c). Flagging out of the national registry is one response by shipowners to the constant upward pressure on the cost of crews; other shipowners have reduced crew numbers as a means of cost containment.

Drewry (1984) reported a trend towards a narrowing of the cost gap between the FOC and traditional maritime operators. However, given the information presented in Table 7.9, indicating that wages for Filipino seamen are extremely high in comparison with other industries in the Philippines, and given the high unemployment among Filipino seamen, it would appear that low cost seamen from less developed countries will be available for a considerable time. Under these circumstances, it will be difficult for the ITF to reduce the gap between FOC and traditional maritime nations' crew costs.

In the high cost countries, crewing scales are expected eventually to reduce to the level of 12 to 14 men on newbuildings. Nevertheless, Japanese costs are expected to remain high due to their complex wage awards, based on a seniority system with large numbers of allowances and a high reserve to active seamen ratio, which would tend to increase when lower crew sizes are achieved. As other traditional maritime nations have instituted crew modernisation programs, the pressure on Australia to continue reductions in crew sizes will be maintained in order that Australian shipping remain competitive. Shipowners' decisions on crew reduction will depend on the balance between the costs of modern equipment, as well as required training or retraining of crew, and the savings in operating costs through smaller crews. It is evident that the future crews, comprising fewer but better trained personnel, are likely to demand increased pay in recognition of their increased responsibilities and skills; that is, the benefits of reduced crew numbers will not accrue in their entirety to shipowners, but will most likely be shared with the seamen.

In the immediate future, while low freight rates bring low returns on newbuildings, shipowners will probably employ, where they can, part or total foreign crews to take advantage of their low local rates of pay and, thereby, help to maintain their presence in the market. In the longer term, owners remaining with national flags will pursue the policy of a smaller but better qualified and paid crew.

SUMMARY

International comparisons of crew costs should be based on the total remuneration received by seamen and all relevant on-costs. Comparisons based on basic wages alone are invalid as they ignore the effect of allowances and overtime payments which are consolidated into Australian seamen's basic wages but are usually paid as separate items in other countries.

When all costs are considered, Australian crew costs per berth are reasonably equivalent to berth costs in other developed countries. They are much less than berth costs in Japan and the USA. However, the relative costs are sensitive to exchange rate variations.

When manning levels are combined with the costs per berth to give total crew costs, Australian ships with a 26-person crew have 20 to 30 per cent higher crew costs than new ships in other developed countries. Exceptions are Japan and the USA which have higher total crew costs than Australia. If new Australian ships with a 21-person crew are used as the basis of comparison, Australian crew costs are closer to, but still higher than, costs experienced by other developed countries

Australian crew costs per berth are approximately 3.1 times greater than labour costs in manufacturing. This ratio is similar to that estimated for other OECD countries.

CHAPTER 8 CAPITAL COSTS

Capital costs account for the largest portion, 40 to 50 per cent, of owners' fully built-up operating costs (Drewry 1984). In this chapter, the factors which can, in theory, influence capital outlays for new and second-hand ships are first discussed. These factors, however, are only partially incorporated into two ship price regression models which are developed in subsequent parts of the chapter. From these regression models, newbuilding and second-hand ship prices are estimated, and these price estimates form inputs to a discounted cash flow algorithm which generates annual capital charges. These derived capital charges become the capital cost components of the overall operating cost model set out in Chapter 9.

FACTORS THEORETICALLY DETERMINING THE NEWBUILDING PRICE OF A SHIP

The major technical and financial determinants of the newbuilding price of a ship are set out in the following paragraphs.

Ship specification

Ship specification has an obvious effect on capital outlays and operating costs. Before any decision is made to invest in a new ship, it is necessary to specify a design which best meets the technical requirements of the particular trade, while complying with the owner's capital and operating cost constraints.

Technical parameters of ship design, such as vessel size, overall length, beam, draught and other dimensions, including tonnage, have to be established. Operational parameters need to be examined in detail to provide for the optimum utilisation and adaptability of the vessel to the trade route and the cargo.

This will involve the following:

- definition of size of the crew;
- estimation of speed and fuel consumption, as well as prediction of fuel price trends to allow for the proper choice of propulsion unit;

- estimation of operational vessel life, load factors, voyage characteristics, such as features of the trades and routes, including distances; and
- forecasting of port costs, including turnaround times, number of port calls, bunkering pattern, handling equipment needed, shore investment required and identification of restrictions in ports and canals on the intended trade route.

All these aspects will need detailed consideration to determine the optimum vessel configuration.

Market conditions

There will be an expectation that the initial capital outlay will be recouped through profitable operation throughout the ship's life. Therefore, a forecast of trade is fundamental to the investment decision.

Trade prospects are most difficult to forecast as international trade is unpredictable by nature and vulnerable to the political climate which can change entirely within the time scale of the project. Shipping is clearly dependent on the trade cycle through the impact of trade fluctuations on the shipping freight market. Shipping demand, and the timing of regular trade cycle peaks and troughs, tend to follow world economic trends. While demand influences the timing of peaks and troughs, supply factors seem to determine the actual range of freight rate movements. Market expectations are an important element on the supply-side, because the size of the fleet is the direct result of ordering, lay-up and scrapping decisions of shipowners (Organisation for Economic Co-operation and Development 1986).

Most commodities in seaborne bulk trades are primary products such as ores, minerals and agricultural products. High volume trades of relatively low value bulk commodities such as iron ore, coal and wheat account for more than 63 per cent of total seaborne trade of bulk commodities by volume (Drewry 1985a) and can be treated as representative of the market because of their significant impact on freight rate trends. Iron ore and coal are generally traded directly between producers and consumers in long-term transactions. By contrast, wheat is traded in short-term transactions between grain houses and importers.

The shipped tonnage of the biggest seaborne commodity by volume, iron ore, fell for four consecutive years from a peak in 1979. Depressed steel production levels and consequent world demand for iron ore, resulted in lower traded volumes. There was some recovery in the years 1984 to 1986, although seaborne trade still remains below the level of 1979. Coal and grain continued to increase steadily in traded volumes, with coal achieving a peak in 1985 and grain reaching a peak in 1984. Total traded volumes of iron ore, coal, grain, bauxite/alumina and phosphate rock are set out in Table 8.1.

TABLE 8.1 TOTAL TRADE, GRAIN FREIGHT RATES, ORDERS AND CONTRACT PRICE DATA TRENDS FOR BULK CARRIERS, 1976 TO 1986

Year	*Total seaborne trade (m tonnes)*	*Grain single voyage charter rate (US$/tonne)*	*Shipping tonnage ordered (m dwt)*	*Existing fleet size (m dwt)*	*Contract average price 25-30000 dwt (US$m)*
1976	646	9.1	9.3	105.7	11.8
1977	645	8.7	6.3	116.6	11.0
1978	668	11.3	1.4	129.6	12.6
1979	762	20.9	10.4	134.9	14.3
1980	796	27.5	18.7	137.7	15.9
1981	806	23.9	15.6	142.1	18.6
1982	759	16.4	5.8	154.7	17.8
1983	732	16.4	18.7	169.2	17.8
1984	833	15.0	11.2	178.1	13.9
1985	857	16.2	6.5	187.8	11.3
1986	834	12.3	5.7	197.5	11.6

Sources Fearnleys (1987). Drewry (1984, 1985b, 1986). Lloyd's Shipping Economist (1985, 1986b, 1987a).

With all these major commodities exhibiting either stagnant or declining trade since 1985, the dry bulk market is currently in recession. Growth of seaborne trade in 1979 and 1980 resulted in freight rate increases and, ultimately, in ordering activity in 1980 (Table 8.1). However, high traded volumes in 1984 and 1985 did not result in freight rate increases and did not lead to new orders as substantial excess supply already existed. This was estimated by Lloyd and Clarksons to be around 45 million dwt which is equivalent to about 30 per cent of the demand level (Organisation for Economic Co-operation and Development 1986).

Delivery time

Depending on the specification of the vessel, a period of between 2 and 4 years may elapse between the order and delivery of a new ship; thus, the outlay on delivery may vary from the order price in terms of international currency values. The shipowner has to wait out the period of vessel construction and may have to forgo the benefits of buoyant market conditions prevailing during that period.

DECISION TO PURCHASE A NEW OR SECOND-HAND SHIP

Generally, a new ship is far more expensive to purchase than a second-hand one, but financial aids, such as building or shipyard export subsidies, government grants and cheap credits, may be available. Also, government shipping policies can alleviate the capital burden of new tonnage by offering tax relief benefits, favourable depreciation allowances or other relief measures.

The buyer of a second-hand vessel, on the other hand, may not be able to obtain credit or government subsidies for the purchase and modification of the ship and will, therefore, have to rely on less attractive financing arrangements. These tend to attract higher interest rates and shorter repayment periods.

Nevertheless, second-hand ships can be an attractive option in view of the generally lower capital costs and the fact that the prices for second-hand tonnage are not static, but are determined by the forces of supply and demand in the world market. Hence, when many vessels are laid up in times of depression (low freight rates) for an extended period, prices tend to fall as owners in financial difficulties sell relatively modern ships to gain liquidity. Some owners take advantage of the fluctuation in second-hand prices and, being able to buy and sell at relatively short notice, trade in ships rather than with ships.

Ship specifications

A major advantage of a new ship is that the vessel can be designed to suit specific needs and also, to take advantage of available modern technology. This will influence the ship's operational efficiency, while draught and breadth can be optimised for the particular trade. The higher initial capital cost can be traded off against expected operational cost savings. For example, a fuel efficient engine, despite its higher price, can provide significant cost savings. Second-hand tonnage is more likely to be obsolescent in the face of rapid technological change, especially in propulsion systems (see Chapter 5). Also, the transfer of a ship from one registry to another may require additional conversion or modification, which would increase the capital cost.

Operating costs

A modern newbuilding usually costs less to operate than an older ship. The main cost difference is due to higher fuel consumption in older vessels. Other costs, which tend to increase, are insurance premiums and maintenance costs.

Relative prices

The relative prices of second-hand ships and newbuildings are major determinants in the choice to buy a new or second-hand vessel. Both newbuilding and second-hand prices are responsive to the state of the freight market. When there is excess demand in the market for freight services, freight rates will be high and the demand for newbuildings and second-hand vessels will increase, with a consequent increase in prices. However, because of the time lag between order and delivery, new ships ordered when excess demand existed, may be delivered during a period of excess supply, thus exacerbating the downturn in the market.

In contrast, the relatively short delivery times in the second-hand market means that second-hand prices can respond much more quickly to conditions in the freight market. Tolofari, Button and Pitfield (1987) found a significant positive correlation between second-hand tanker prices and an index of freight rates in the month of the sale. The response to freight market conditions means that the ratio of second-hand to newbuilding prices can vary markedly from year to year. This, in turn, will strongly influence the choice to buy a new or second-hand ship.

Table 8.2 illustrates the variation in charter rates, newbuilding and second-hand prices. The table shows that second-hand prices generally follow charter rates, but show much less variation. On the other hand, newbuilding prices show much less change with the consequence that the ratio of second-hand to newbuilding prices showed marked variation over the 4-year period.

Methods of financing

The method of financing can influence the amount which a prospective owner is prepared to outlay for a ship. Assuming all other things are equal, a higher financing cost will mean a lower priced ship will become attractive. Governments have typically supported their shipbuilding industries either by directly supporting shipyards

TABLE 8.2 FREIGHT RATES AND PRICES FOR A 120 000 DWT BULK CARRIER

Year	*Single voyage rates (US$/ton of cargo)*	*1 year time charter (US$'000/day)*	*Newbuilding price in Japan (US$m)*
1983	5.0	6.1	32.0
1984 average	6.0	7.9	27.7
1985 average	5.1	7.5	26.5
1986 average	3.7	6.1	25.0
1987 March	3.5	7.0	25.0
Year	5-year old second-hand (US$m)	Ratio of second-hand to newbuilding prices	Demolition in Taiwan (US$m)
1983 average	10.4	0.325	2.1
1984 average	13.0	0.469	2.5
1985 average	10.7	0.404	2.5
1986 average	10.3	0.412	2.6
1987 March	14.0	0.560	2.9

Source Lloyd's Shipping Economist (1986a, 1987b).

through subsidies and other measures that have the effect of reducing the capital cost, or by less directly reducing the cost of financing the purchase of the ship. In general, the sources of finance for a new ship are quite varied. The United Nations (1985) and Lloyd's (1987) presented the following list as typical:

- shipowners' equity generally about 20 per cent;
- subsidies offered by governments or shipyards;
- domestic loans provided by governments for domestic shipyards;
- foreign loans provided by governments for foreign yards;
- incentive grants or loans for domestic yards;
- export credits guaranteed by governments and provided by other institutions for new vessels to enable domestic shipyards to compete on the open market;
- bank loans repayable through special arrangements, such as profit sharing, special terms or mortgages;

- leasing or sale arrangements over 15 years or longer with commercial banks, which are attractive options to shipowners as they release financial resources and allow the owners to use the assets; and
- loans from specialised institutions, such as ship mortgage banks or insurance companies.

In 1979 the OECD, in assessing the problems associated with the world tonnage oversupply, noted that many governments devoted large sums of money to support shipyards by offering assistance with deposits, longer credit periods, low interest rates, interest subsidies, subsidised contract prices, loan grace periods and so on. In order to discourage this credit competition between the major industrialised countries, the OECD established maximum agreed permissable terms on loans to non-nationals for the purchase of ships exported by signatories to the OECD (Drewry 1984).

OECD financing

The major conditions, operative since 1979, of the OECD maximum agreed permissable terms' credit scheme are that:

- the maximum loan consists of 80 per cent of ship contract price;
- the interest rate is 8 per cent per annum; and
- the period for repayment equals 8.5 years from the date of delivery.

The allowable credit terms have been modified from time to time according to the world shipbuilding and financial situation, but have remained stable since 1979. Changes in interest rates and terms occurred before 1979, as shown in Table 8.3.

TABLE 8.3 CHANGES IN OECD FINANCE TERMS

Year	*Deposit (percentage of purchase price)*	*Term (years)*	*Interest (per cent per annum)*
1969	20	8.0	5.5
1970	20	8.0	6.0
1971	20	8.0	7.5
1974	30	7.0	8.0
1979	20	8.5	8.0

Source Drewry (1983).

An important advantage of these terms is that they carry fixed interest rates, thus providing immunity from the risk of interest rate fluctuations.

Export subsidies and other government grants are generally only available for newbuildings. The financing of second-hand ships is usually arranged through commercial channels. In recent years, freight rates have been so low that most financial institutions have been reluctant to finance such acquisitions, unless a shipowner provides substantial equity and solid loan securities. Higher interest rates and shorter loan periods generally apply to second-hand purchases (Drewry 1985).

Timing of acquisition

Shipowners' decisions to order new ships are generally stimulated by rising freight rates. During the buoyant market conditions of 1979, 1980 and 1983-84, increases in volumes ordered were observed. By the time ships ordered during the buoyant periods were delivered, trading conditions had deteriorated significantly, leaving the shipowners with surplus tonnage, thereby adding to a world oversupply and aggravating the shipbuilding recession (Cashman 1985).

When freight rates are low, shipowners should logically refrain from ordering new ships. However, intensified protectionism in the form of subsidies, export credits and favourable finance provided for national industries, encourages demand for new tonnage. Government intervention in the open market clouds the overall picture of world shipbuilding. In Cashman's (1985) view, the recession in the shipbuilding industry has lasted for 15 years, causing overtonnage to grow steadily. However, for the first time since annual records were kept, the total bulk carrier fleet contracted by 1 per cent between January 1986 and January 1987 (Fearnleys 1987), and this contraction may precede more significant reductions in overtonnage and possible improvements in market prices and rates.

As second-hand tonnage is delivered at the time of sale or very soon afterwards, shipowners can take immediate advantage of rising freight rates and buoyant markets. The early months of 1987 saw one example of this occurrence, when increased Soviet wheat purchases resulted in a firming of charter rates and second-hand ship prices.

NEWBUILDING PRICE MODEL

There are many methods to estimate the price of a new ship. For example, a shipowner would be able to obtain reasonably detailed estimates for building a specific new ship for a specific purpose. The method adopted depends on the purpose for which the result is to be used. The BTCE, in its work, requires a simple model that relates newbuilding prices to deadweight tonnage. The model would also suffice where a general type of analysis was required.

The BTCE established a relationship between price and deadweight tonnage of new bulk ships by estimating a model of the form:

$$P = c_0 \, DWT^{c_1} \, a \tag{8.1}$$

or, after logarithmic transformation,

$$\ln P = \ln c_0 + c_1 \ln DWT + \ln a \tag{8.2}$$

where:

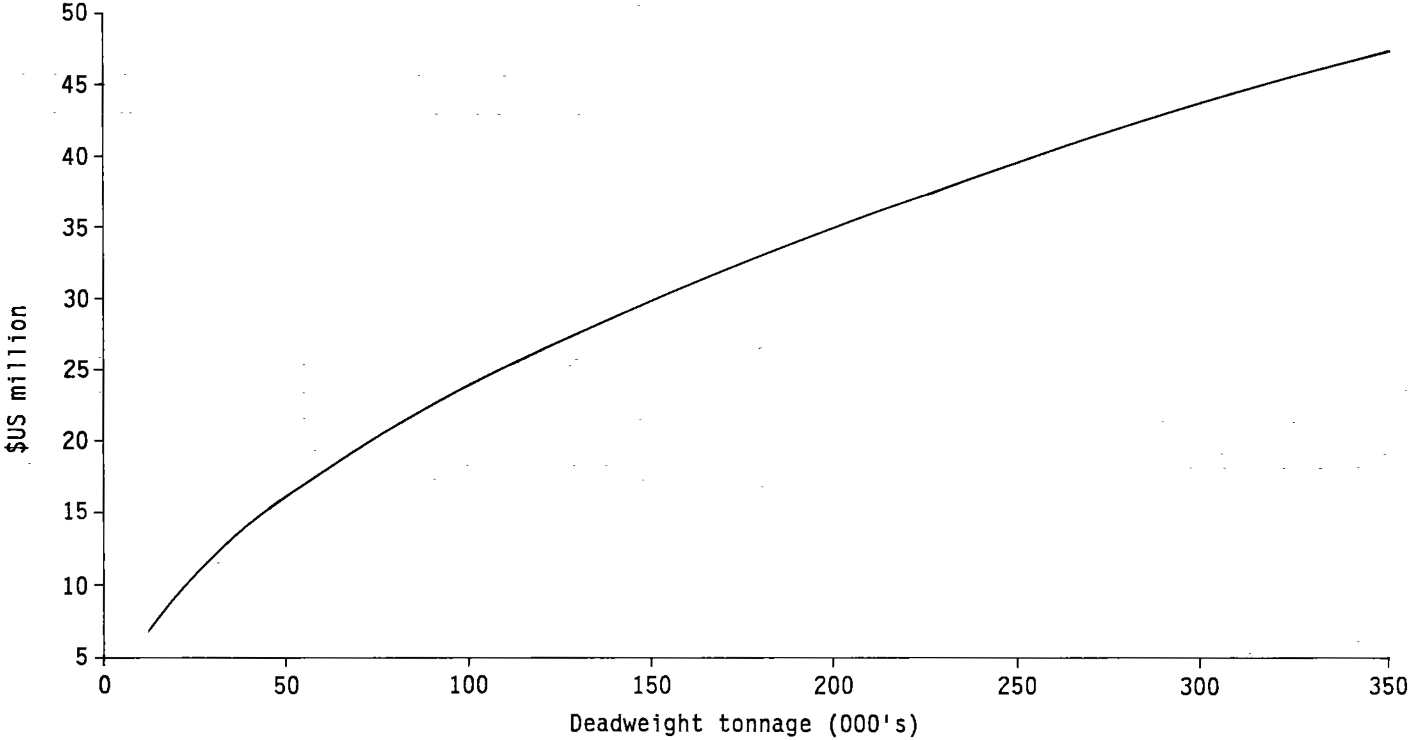
P = newbuilding price (US$'000);
DWT = size of the ship ('000 dwt);
c_0, c_1 = coefficients to be estimated;
a = error term;
ln = logarithms to the base e.

The data used in the analysis were derived from the Fairplay list of 1984 newbuildings contract prices (Fairplay 1985), except for three Broken Hill Proprietary Ltd ships for which prices came from BRL Shipping Consultants (1985). Original prices for new ships, ordered in different world shipyards, were converted into US dollars using average 1984 exchange rates. The model was estimated using the ordinary least squares method. A test was carried out using dummy variables to check whether the Korean prices were having a depreciating effect on other shipyards' prices. The test showed that there was no significant difference between Korean prices and those of other shipyards.

The model resulting from the analysis is, with t-statistics in parentheses:

$$\ln P = \underset{(69.4)}{7.4922} + \underset{(53.3)}{0.5597} \ln DWT \tag{8.3}$$

The estimated relationship for ship sizes from 1500 to 350 000 dwt has a very high coefficient of determination (R^2) equal to 0.97. The residuals (the difference between predicted and observed values) pass the test for normality. The results are presented graphically in Figure 8.1.



Source BTCE estimates.

Figure 8.1 Newbuilding price - deadweight tonnage relationship

SECOND-HAND PRICE MODEL

A model of second-hand prices was estimated using 105 second-hand bulk vessel prices taken from Drewry's Shipping Statistics and Economics (1985b, 1986). Clearly, second-hand prices depend on the age of the vessel and the price of new vessels of equivalent size. It is possible that second-hand prices might also be a function of the size of the ship. The model estimated accounts for all these variables and takes the form:

$$D = c_0 \, DWT^{c_1} \, e^{c_2 AGE} \, a \qquad (8.4)$$

or, in logarithmic form:

$$\ln D = \ln c_0 + c_1 \ln DWT + c_2 \, AGE + \ln a \qquad (8.5)$$

where

D	=	the ratio of second-hand price to the estimated newbuilding price;
AGE	=	age of the ship (years);
DWT	=	size of the ship ('000 dwt);
ln	=	logarithms to the base e;
c_0, c_1, c_2	=	coefficients to be estimated;
a	=	error term.

The model, estimated by ordinary least squares regression analysis is, with t-statistics in parentheses:

$$\ln D = \underset{(-2.22)}{-1.2035} + \underset{(3.95)}{0.2001} \ln DWT - \underset{(-19.8)}{0.1018} \, AGE \qquad (8.6)$$

All of the coefficients are significant, with the coefficient of the DWT variable indicating that larger ships depreciate at a slower rate than smaller ships. The equation is valid only for second-hand ships sold in 1985-86. Given the volatility of second-hand prices, the equation should be used with caution and may not be valid for ships sold in years other than those used in the analysis.

CAPITAL CHARGES AND THE CAPITAL RECOVERY RATIO

For the BTCE's analytical purposes, it is necessary to estimate capital charges on a daily basis. A method of incorporating the purchase price in future cash flows, proposed by Goss (1985), is to identify the series of payments for the proposed loan (interest, principal and other charges inclusive), reduce these to a present value amount at the same rate of discount as that used for the rest of the analysis, and then substitute the result for that part of the purchase price which is covered by the loan. In this way, the present value of the loan principal is lower than the actual loan amount and leads to a higher net present value for the whole project. However, this approach does not allow for the owner's equity amortisation and any financial return on that equity. Also, the loan repayment period is usually shorter than the economic life of the vessel; thus, financial terms calculated on this basis do not constitute a complete framework for calculating long-term average or daily capital charges. For ships which are trading in the open market, the equivalent capital charges method, based on the loan and credit terms as well as a capital recovery formula, is a commonly accepted approach for calculating daily financial surplus. In practice, the resulting capital charges represent measures of the short-run opportunity cost of the ship and can be easily compared to charter rates and to ship prices on the market.

Drewry (1983) recommended that for long-term planning, the OECD loan terms and discounted cash flow technique be used to calculate the break even freight rates. In particular, the principal repayments on the loan, interest payments and return on equity, are combined and discounted back to a single net present value at the year of delivery. This approach was adopted for the analyses in this Paper. Typical calculations are shown in Appendix X. In these examples, depreciation is calculated by the conventional straight line method over the 15-year life of the ship. No allowance is made for residual value at the end of the ship's life, as the discounted value is relatively small.

As will be seen in the examples, the combined net present value of the loan principal repayments, interest and return on equity is converted into a constant annuity by using a capital recovery formula; that is, the net present value is converted into equal annual capital charges over the life of the ship. The ratio of the annuity value to the initial purchase price gives the capital recovery ratio.

Examples of annual capital charge calculations for a new and a second-hand 65 000 dwt bulk carrier are provided in Appendix X. Two examples allow for a return on equity of 10 per cent per annum, while the other examples are based on zero return on equity. In a depressed freight market, rates often decline to a level where shipowners must forgo any return on equity. Generally, however, they would still expect to recover the loan repayments from their operations. The examples, in which return on equity is zero, are designed to illustrate the effect of depressed freight markets on the capital recovery ratio. For instance, the capital recovery ratio with a 10 per cent per annum return on equity is 17 per cent. This declines to 14 per cent for the same ship with zero return on equity.

The capital recovery ratio is higher for second-hand ships, being 20 per cent in the example for which equity of 50 per cent is assumed. The high capital recovery ratio occurs because of the short repayment term of five years and the higher interest rate of 14 per cent per annum. These financial terms are consistent with those assumed by Drewry (1983). If the second-hand shipowner does not allow for any return on his equity, the capital recovery ratio drops back to 16 per cent.

A typical long-term investment strategy would mean that a shipowner allow for a positive return on his equity; thus, credit terms will be an important factor in the decision to invest in a new or second-hand vessel. However, while the capital recovery ratio is higher for a second-hand ship, it is based on a lower initial capital investment so that the annual capital charge can be significantly lower for a second-hand ship.

PROSPECTS FOR BULK CARRIERS

Future ship prices will be determined mainly by underlying long-term construction costs and potential freight market conditions.

Reduction in new bulk carrier orders, combined with strong competition from Far Eastern countries (South Korea, Taiwan) and Comecon countries (China, Yugoslavia, Poland), has exerted downward pressure on newbuilding prices. This trend is likely to continue in the near future. Korean yards have become very competitive in US dollar terms. Only a low rate of price escalation (2 per cent per annum in real terms) was forecast by Ocean Shipping Consultants (1985), generated mainly by increases in shipyard costs (for example, labour). Credit terms and financial packages, which can be crucial determinants of investment decisions are impossible to forecast, but continued domestic government intervention (in the form of export subsidies, tax-offsetting allowances and other measures) is expected.

Dry bulk market conditions

Even though the spot dry bulk market sector is characterised in economic terms as a 'perfect' market, shipowners have not been able to cover all costs and make 'normal' profits over the past 5 to 6 years (Lloyd's Shipping Economist 1987c). The 'perfect' market has been distorted by oversupply, amongst other factors. An improvement in the situation would result if surplus tonnage was reduced. The most likely scenario for the next three years, according to Lloyd's Shipping Economist (1987c), is that the surplus will fall from 27 per cent in 1987 to 16 per cent in 1989. This reduction will improve the overall situation, but will not have any significant effect on freight rates.

Fearnleys (1987) has attempted to quantify the tonnage development up to 1990, forecasting a decline in the bulk carrier fleet of 12 million dwt (from 196 million dwt in 1987, to 183.7 million in 1990). This forecast was based on estimates of scrapping trends, the existing order book and expected new orders with delivery before 1990. However, these estimates should be treated with caution, because changes in market conditions can rapidly influence decisions to build or scrap vessels. For example, shipowners often delay scrapping decisions, believing that a temporary rise in freight rates will continue.

Nevertheless, recognising the market stagnation due to overtonnage, shipowners must hope for an improvement in the demand for bulk shipping services or accept higher scrapping volumes. Initially, scrapping rates for 1986 and 1987 were estimated to be between 6 and 6.5 million dwt per year by Hattori (1984). However, this estimate appears low, as the Institute of Shipping Economics and Logistics (1987) reported that total bulk tonnage sold for scrap in 1986 was 11.9 million dwt.

Prospects for the seaborne trades and freight rates do not appear optimistic. Even before the stock market crash of 1987 and the consequent growing uncertainty regarding commodity prices, it was not expected that trade volumes of main dry bulk commodities - iron ore, coal and grain - would improve before 1990 (Ocean Shipping Consultants 1985). If any improvement does occur, it would probably be insufficient to lower the bulk carrier tonnage surplus to the required level.

Vessels over 100 000 dwt, which are employed mainly in the iron ore and coal trades, serve the steel industry which has prospects of only sluggish demand growth. This, coupled with already existing over-capacity, does not augur well for the recovery in the large bulk carrier sector (Drewry 1983).

Panamax bulk carriers engaged in coal and grain trades do not appear to have much better prospects than large carriers. Only modest growth in total seaborne coal trade is expected after 1990, in line with iron ore. There are some forecasts for good steaming coal trades, although they may be impeded by falling oil prices and slow industrial growth.

Only seaborne grain movements are likely to improve over the period 1987 to 1990; thus, Handy-sized bulk carriers would seem to have better profit prospects than other bulk carriers (Drewry 1983).

SUMMARY

Prices for new ships depend on the size of the ship and other design specifications. Prices are also strongly influenced by the financing methods agreed to by the builder and the buyer. Prices of new ships respond to the state of the bulk shipping market but are not as volatile as second-hand prices.

A model relating published new shipbuilding prices to ship size for ships ordered in 1984 was developed. The model indicates that there are economies of size in the capital costs of new ships with prices increasing by 5.6 per cent for a 10 per cent increase in size.

Similarly, a model relating the ratio of second-hand prices of bulk ships sold in 1985 and 1986 and new shipbuilding prices to ship size and age was estimated. For every 10 per cent increase in ship size the ratio increases by 2 per cent which indicates that larger ships depreciate at a slower rate than smaller ships. The ratio is very dependent on age and decreases by about 10 per cent for each increase in age of 1 year.

Given the volatility of second-hand ship prices, this latter model may not be relevant for ships sold in years other than 1985 and 1986.

CHAPTER 9 OPERATING COST MODEL

The three major components of bulk ship operating costs are capital costs, crew costs and fuel costs. Estimates of crew costs and capital costs were discussed in Chapters 7 and 8 respectively. A method for estimating fuel consumption was introduced in Chapter 5. This chapter draws on these previous analyses, introduces other cost components and then combines all cost categories into an overall model of dry bulk ship operating costs.

FUEL COSTS

Most marine propulsion engines now utilise the heavier and cheaper fuel oils such as HVO CST-390. Auxiliary engines are also more likely to be designed to use the heavier oils. Depending on geographical areas, the difference between prices for fuel oil and diesel oil could vary significantly. Also, in the current market, fuels are traded on spot market rather than on contract basis as prices cannot be forecast (Fairplay 1986).

One way of reducing fuel costs is to practise slow steaming. Since the 1973 oil crisis slow steaming has become a common practice, bringing down fuel consumption levels significantly. While slow steaming can lead to a reduction in bunker cost by an average of 20 per cent (Drewry 1984), voyage times will increase and this, in turn, will increase capital and other operating costs per voyage. These increased costs can outweigh the savings on fuel costs. For some older engines there are also some technical limitations on the amount of slow steaming that can be practised. The analyses in this Paper assume that slow steaming is not practised. Furthermore, the analyses in this and the next chapter assume that fuel consumption is given by the Chapter 5 models on installed power and specific fuel consumption. Fuel prices of US$104 per tonne for heavy viscosity oil and US$149 per tonne for marine diesel oil current in May 1987 were assumed.

REPAIRS AND MAINTENANCE COSTS

Repairs and maintenance (R&M) costs are necessary expenses incurred in keeping the vessel in operation for the maximum time, having regard to safety, statutory obligations laid down by the country of registration, service standards by ship classification societies and shipowners' individual policies. R&M costs vary widely between ships of similar size according to age, condition and ship technology.

Routine maintenance expenses during the assumed 15 days down-time period per annum are scheduled in advance and are reasonably predictable. However, unexpected delays and repairs due to breakdowns, damage or collision are extremely difficult to forecast.

Some maintenance and minor repairs can be carried out by crew during ship operations and this cost is not included in the R&M item. Excluding these repairs, total repairs and maintenance costs can be expressed as a percentage of the ship price on an annual or daily basis. In accordance with the assumption made by the World Bank (1986) in its cost model, annual R&M costs for the purposes of this study are assumed to be 1.4 per cent of the vessel price for newbuildings plus an additional 10 per cent of the estimated R&M costs for second-hand ships.

STORES AND LUBRICANTS COSTS

These costs consist of expenditure on spare parts, deck and engine room equipment and lubricating oil. They are estimated by a fixed percentage of 1 per cent of the new vessel price in the BTCE cost model, parallel with the 1 per cent of the replacement value assumed in the World Bank cost model (World Bank 1986). For second-hand ships, an additional 10 per cent of the stores and lubricants' cost estimate is added.

ADMINISTRATION COSTS

Administrative overheads associated with crew employment and travel, the purchase of ship supplies and fuel from port agents, arranging for ship maintenance and repairs, and other factors, are extremely difficult to allocate to a particular ship. In this analysis it is assumed that these costs can be estimated as 10 per cent of crew and R&M costs (World Bank 1986, 176).

INSURANCE COSTS

The Hull and Machinery (H&M) Insurance for a ship represents protection against physical damage or loss. The insurance premiums are generally based on the value of the ship and its physical parameters; in the BTCE cost model, the cost of H&M insurance is estimated as a fixed percentage, 0.6 per cent, of the ship price.

The liability to third parties (P and I) insurance, estimated by the World Bank to be another 0.6 per cent of the ship replacement value, was treated as an element of crew costs in Chapter 7 and was not incorporated in this cost category.

BTCE COST MODEL

By combining the preceding cost categories with the other primary cost components detailed in Chapters 7 and 8, the BTCE developed its overall dry bulk ship cost model. In Tables 9.1 to 9.3 the operating cost components for various new bulk ships, as derived by the BTCE cost model, are set out. Australian crews and May 1987 fuel prices are assumed. Figures 9.1 to 9.3 present the same information graphically. Tables 9.4 to 9.6 detail the corresponding information for 5-year old bulk carriers of various sizes.

The most obvious feature of Tables 9.1 to 9.6 is the significant trade-off between capital and crew costs. In particular, the proportion of capital costs within the total cost structure rises dramatically as the ship size increases, while simultaneously the proportion represented by crew costs falls. The other cost component shares are relatively stable.

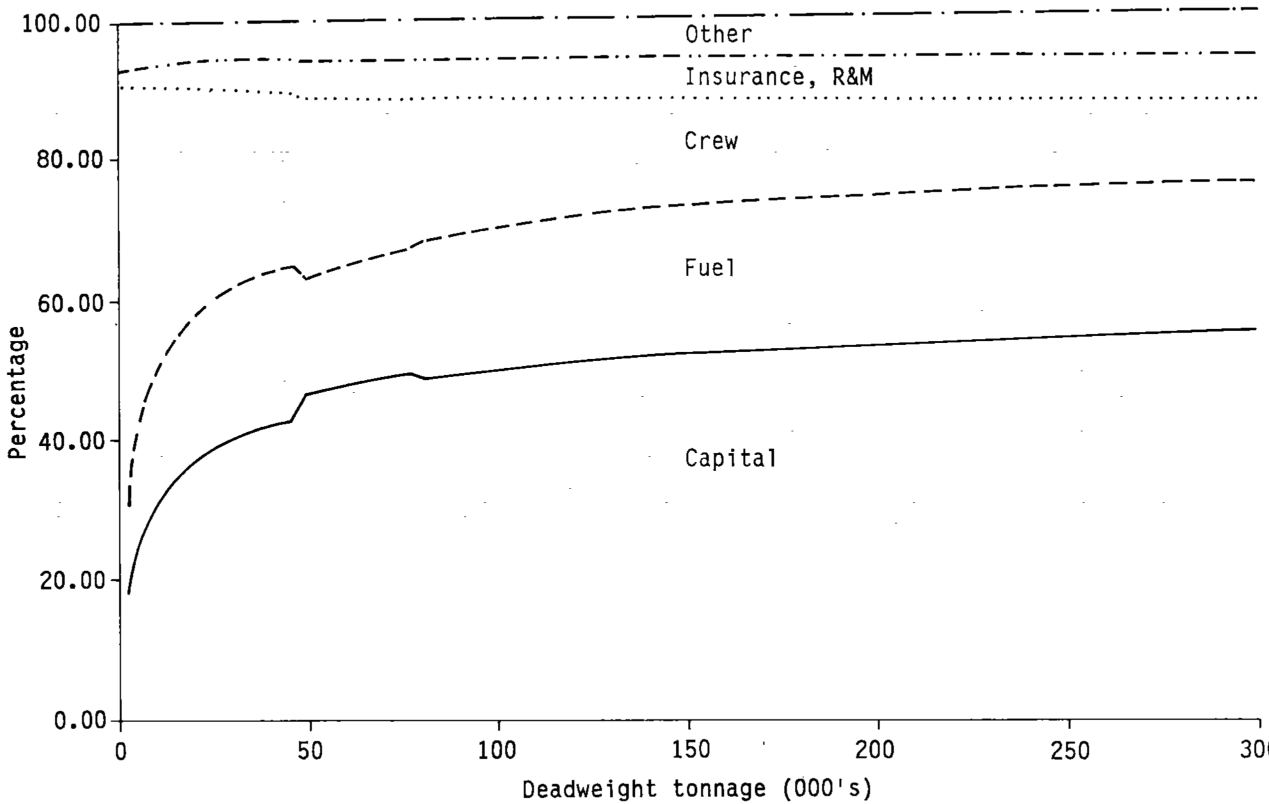
It is also interesting to note that per 1000 dwt and per day, the total operating costs of the second-hand vessels are 32 to 35 per cent less than those of the corresponding new carriers.

TABLE 9.1 PERCENTAGE DISTRIBUTION OF PRIMARY OPERATING COST COMPONENTS FOR A NEW BULK CARRIER

(per cent)

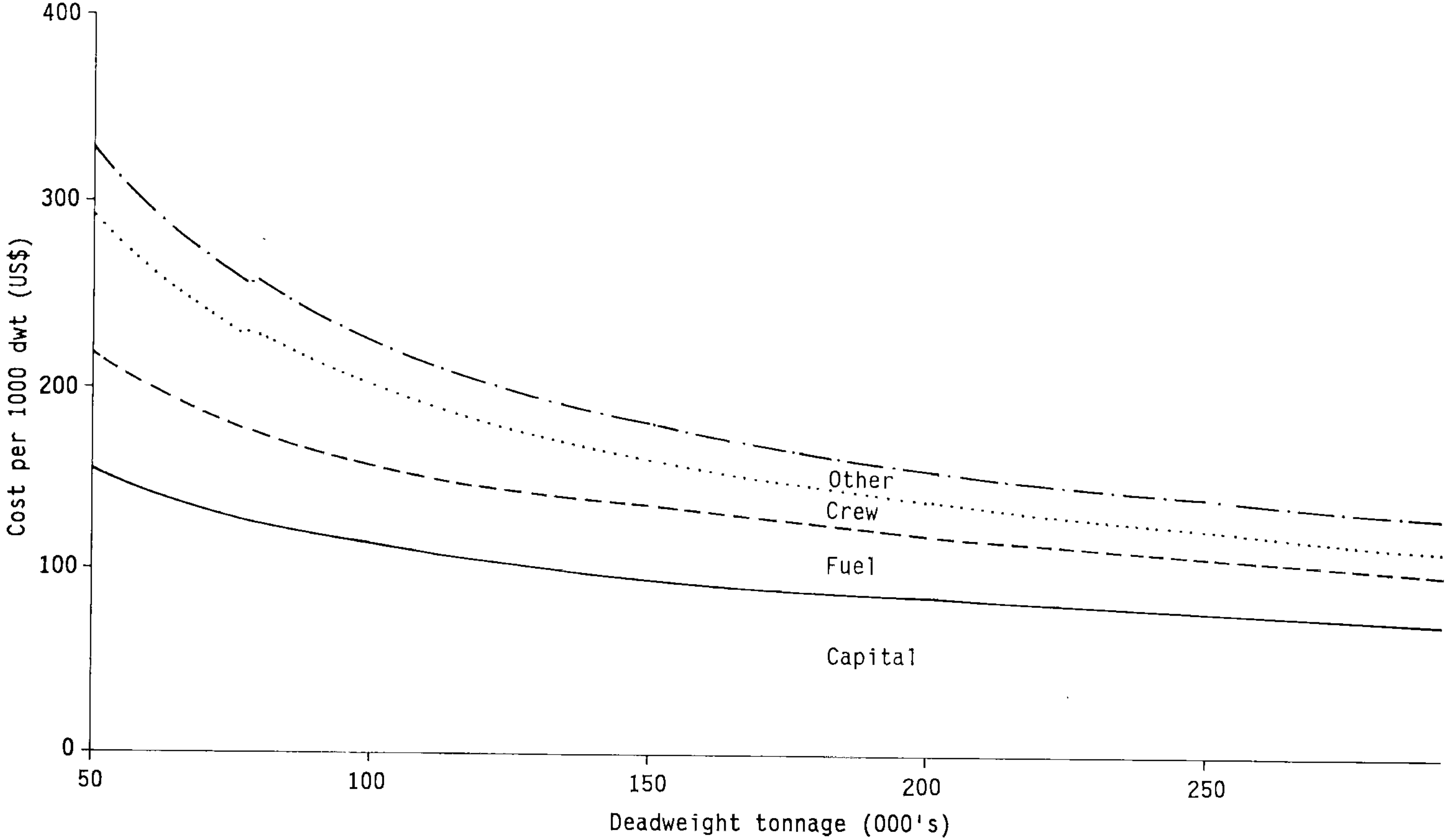
	Cost component					
Size (dwt)	*Capital*	*Fuel*	*Crew*	*Insurance R&M*	*Admin and others*	*Total*
20 000	36.6	20.7	32.7	4.3	5.7	100
60 000	47.8	18.0	23.1	5.6	5.5	100
120 000	51.4	20.6	16.8	6.0	5.2	100
200 000	54.2	21.1	13.3	6.4	5.0	100

Source BTCE estimates.



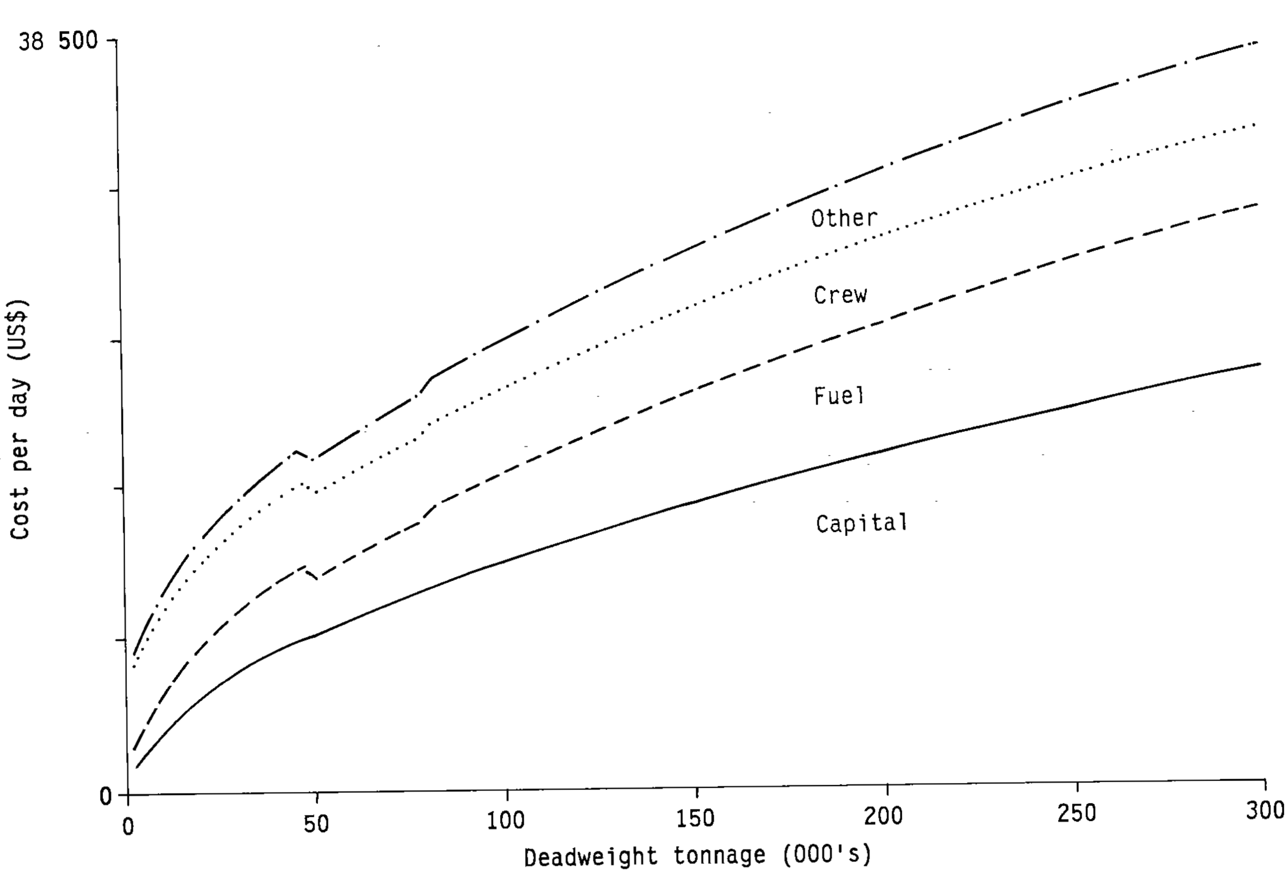
Source BTCE estimates.

Figure 9.1 Cumulative distribution of primary operating cost components for a new bulk carrier



Source BTCE estimates.

Figure 9.2 Cumulative distribution of primary operating cost components per 1000 dwt for a new bulk carrier



Source BTCE estimates.

Figure 9.3 Cumulative distribution of primary operating cost components per day for a new bulk carrier

TABLE 9.2 DISTRIBUTION OF PRIMARY OPERATING COST COMPONENTS PER 1000 DWT FOR A NEW BULK CARRIER

(US dollars)

	Cost component					
Size (dwt)	*Capital*	*Fuel*	*Crew*	*Insurance R&M*	*Admin and others*	*Total*
20 000	233	132	208	27	36	636
60 000	144	54	69	17	16	300
120 000	106	43	35	12	10	206
200 000	85	33	21	10	7	156

Source BTCE estimates.

TABLE 9.3 DISTRIBUTION OF PRIMARY OPERATING COST COMPONENTS PER DAY FOR A NEW BULK CARRIER

(US dollars)

	Cost component					
Size (dwt)	*Capital*	*Fuel*	*Crew*	*Insurance R&M*	*Admin and others*	*Total*
20 000	4 660	2 633	4 160	548	728	12 729
60 000	8 617	3 235	4 160	1 014	994	18 020
120 000	12 702	5 100	4 160	1 494	1 268	24 724
200 000	16 905	6 579	4 160	1 989	1 550	31 183

Source BTCE estimates.

TABLE 9.4 PERCENTAGE DISTRIBUTION OF PRIMARY OPERATING COST COMPONENTS FOR A 5-YEAR OLD BULK CARRIER
(per cent)

Size (dwt)	*Cost component*					
	Capital	*Fuel*	*Crew*	*Insurance R&M*	*Admin and others*	*Total*
20 000	19.1	29.5	44.1	1.9	5.4	100
60 000	32.4	26.7	32.5	3.2	5.2	100
120 000	38.8	29.8	23.0	3.9	4.5	100
200 000	44.1	29.6	17.7	4.4	4.2	100

Source BTCE estimates.

TABLE 9.5 DISTRIBUTION OF PRIMARY OPERATING COST COMPONENTS PER 1000 DWT FOR A 5-YEAR OLD BULK CARRIER
(US dollars)

Size (dwt)	*Cost component*					
	Capital	*Fuel*	*Crew*	*Insurance R&M*	*Admin and others*	*Total*
20 000	90	139	208	9	26	472
60 000	69	57	69	7	11	213
120 000	59	45	35	6	6	151
200 000	52	35	21	5	5	118

Source BTCE estimates.

TABLE 9.6 DISTRIBUTION OF PRIMARY OPERATING COST COMPONENTS PER DAY FOR A 5-YEAR OLD BULK CARRIER
(US dollars)

	Cost component					
Size (dwt)	*Capital*	*Fuel*	*Crew*	*Insurance R&M*	*Admin and others*	*Total*
20 000	1 801	2 781	4 160	180	519	9 441
60 000	4 150	3 418	4 160	414	653	12 795
120 000	7 027	5 388	4 160	703	817	18 095
200 000	10 359	6 950	4 160	1 036	1 006	23 511

Source BTCE estimates.

SUMMARY

Previous chapters provided estimates of crew costs and capital costs of new and second-hand ships. This chapter provides estimates of the remaining components of ship operating costs to allow total operating costs to be estimated.

The estimates illustrate the trade-off between capital costs and crew costs. Crew costs decline from 33 per cent of total costs for a 20 000 dwt ship to 13 per cent for a 200 000 dwt ship. In contrast, estimated capital costs increase from 37 per cent to 54 per cent over the same size range. Fuel costs, the other major cost component, are reasonably constant over the range 20 000 to 200 000 dwt remaining within the range 18 to 21 per cent of total operating costs.

The model also illustrates the economies of size for dry bulk carriers. Costs per 1000 dwt per day decline from $636 for a 20 000 dwt ship to $156 for a 200 000 dwt ship. In general, operating costs for a second-hand ship are 32 to 35 per cent lower than for a new ship.

CHAPTER 10 APPLICATIONS OF THE COST MODEL

The previous chapter summarised the overall operating cost model developed from the foregoing analyses in this study. This chapter develops the theme further by applying the cost model to a number of applications. These applications cover a number of trading patterns relevant to Australian shipowners and port authorities but are not meant to refer to any specific route. They are hypothetical but nevertheless realistic examples, which illustrate how the cost model can be used to analyse shipping costs or, alternatively, the reduction in shipping costs that can arise from port improvements.

No attempt has been made to estimate the cost of port improvements as these are very much dependent on the specific conditions applying to individual ports. For example, the cost of deepening a channel depends both on the type of material to be removed and the length of the channel.

Four cases are examined. The first two illustrate and quantify the benefits of establishing a triangular trading pattern in which only one of the legs is travelled in ballast. The third case examines the costs of two-port loading and the final application considers the benefits of self-unloaders.

Assumptions, which are common to all cases, are given in Table 10.1.

TABLE 10.1 ASSUMPTIONS COMMON TO ALL CASES

Voyage or cost parameter	*Assumed value*
Fuel cost (heavy viscosity oil)	$A120 per tonne
Fuel cost (marine diesel oil)	$A165 per tonne
FOC crewing levels	33
FOC annual cost per berth	$A25 000
Australian crewing level	26
Australian annual cost per berth	$A93 000
Trading	340 days per annum
Ship speed	14.7 knots
Time entering and leaving port	3 hours
Port charges (Australian)	
National light dues	$A0.55 per net registered tonne per quarter
Tug and launch charges	$A0.20 per gross registered tonne per movement
Other port charges	$A0.30 per gross registered tonne per call
Port charges (foreign)	
Tug and launch charges	$A0.10 per gross registered tonne per movement
Other port charges	$A0.15 per gross registered tonne per call
Stevedoring (Australian)	
Grain	$A5 per revenue tonne
Iron ore and coal	$A2 per revenue tonne
Stevedoring (foreign)	
Grain	$A2 per revenue tonne
Iron ore and coal	$A2 per revenue tonne

Sources National Bulk Commodities Group (1987). BTCE estimates.

CASE 1 - SMALL TRIANGULATION

This case compares the cost of six hypothetical options for transporting minerals. Discharge rates are typical rates as suggested by Gubbins (1986). Assessed loading rates are representative of major loading ports.

(i) A new 70 000 dwt FOC-crewed ore carrier loads 68 000 tonnes of coal at port A, at a loading rate of 8000 tonnes per hour, and sails direct to port B (a distance of 4500 nautical miles) where it discharges its cargo at a discharge rate of 3000 tonnes per hour. The vessel then returns direct to port A carrying ballast only.

(ii) This is identical to (i) except that the vessel is a 150 000 dwt ore carrier which loads 148 000 tonnes of coal.

(iii) A new 150 000 dwt Australian-crewed ore carrier loads 148 000 tonnes of coal at port A at a loading rate of 8000 tonnes per hour; sails 4500 nautical miles to port B where it discharges the coal at a rate of 3000 tonnes per hour. The carrier then sails 3500 nautical miles direct to port C carrying ballast only. After loading 148 000 tonnes of iron ore at port C at a rate of 10 000 tonnes per hour, the carrier returns 3000 nautical miles to port A where it unloads at a discharge rate of 4000 tonnes per hour.

(iv) This is identical to (i) except that the vessel is 5 years old.

(v) This is identical to (ii) except that the vessel is 5 years old.

(vi) This is identical to (iii) except that the vessel is 5 years old.

The foreign ports B and C are assumed to make wharfage charges of $A0.10 per revenue-tonne, while the Australian port A charges $A0.20 per revenue-tonne. Further, it is assumed that the cost of the ballast leg can be appropriately allocated to the load legs in options (iii) and (vi), in proportion to the lengths of these cargo-carrying legs. The results of the analysis are summarised in Table 10.2 (newbuildings) and Table 10.3 (5-year old carriers).

TABLE 10.2 SUMMARY OF COSTS FOR CASE 1 - SMALL TRIANGULATION - NEWBUILDINGS

Voyage parameter	*Case 1 (i) Ore carrier/70 000 dwt/FOC*			*Case 1 (ii) Ore carrier/150 000 dwt/FOC*			*Case 1 (iii) Ore carrier/150 000 dwt/AUS*		
	Leg 1	*Leg 2*	*Leg 3*	*Leg 1*	*Leg 2*	*Leg 3*	*Leg 1*	*Leg 2*	*Leg 3*
Load(tonnes)	68 000	0	..	148 000	0	..	148 000	0	148 000
Commodity	Coal	Ballast	..	Coal	Ballast	..	Coal	Ballast	Iron ore
Distance[a]	4 500	4 500	..	4 500	4 500	..	4 500	3 500	3 000
Cost component[b]									
Capital	218 443	151 753	..	376 100	236 095	..	376 100	184 489	258 801
Fuel	115 510	115 306	..	142 749	142 305	..	142 749	111 200	95 986
Crew	40 619	37 018	..	44 856	37 018	..	131 469	84 782	90 466
Other	38 341	34 464	..	55 049	44 680	..	53 832	34 128	37 043
Port	30 170	24 426	..	62 646	50 735	..	62 646	27 794	50 735
Wharfage	20 400	0	..	44 400	0	..	44 400	0	44 400
Stevedoring	275 447	3 442	..	596 262	4 252	..	596 262	3 323	594 866
Load leg cost[c], FIO[d] terms[b]	826 450	..	..	1 236 633	..	..	1 076 632	..	754 388
Break even revenue required per tonne[b]	12.15	..	..	8.36	..	..	7.27	..	5.10

a. Nautical miles.
b. Australian dollars.
c. Incorporates a share of ballast leg costs, the share being determined by relative load leg distances.
d. Free in and out terms, that is, excludes stevedoring costs.
.. Not applicable.

Source BTCE estimates.

TABLE 10.3 SUMMARY OF COSTS FOR CASE 1 - SMALL TRIANGULATION - 5-YEAR OLD VESSELS

Voyage parameter	*Case 1 (iv)* *Ore carrier/70 000 dwt/FOC*			*Case 1 (v)* *Ore carrier/150 000 dwt/FOC*			*Case 1 (vi)* *Ore carrier/150 000 dwt/AUS*		
	Leg 1	*Leg 2*	*Leg 3*	*Leg 1*	*Leg 2*	*Leg 3*	*Leg 1*	*Leg 2*	*Leg 3*
Load (tonnes)	68 000	0	..	148 000	0	..	148 000	0	148 000
Commodity	Coal	Ballast	..	Coal	Ballast	..	Coal	Ballast	Iron ore
Distance[a]	4 500	4 500	..	4 500	4 500	..	4 500	3 500	3 000
Cost component[b]									
Capital	81 765	58 095	..	157 497	103 661	..	157 497	81 003	108 377
Fuel	125 125	124 921	..	165 934	165 940	..	165 934	129 317	111 570
Crew	40 619	37 018	..	44 856	37 018	..	131 469	84 782	90 466
Other	33 867	30 698	..	49 536	40 615	..	48 319	30 951	33 249
Port	30 170	24 426	..	62 646	50 735	..	62 646	27 794	50 735
Wharfage	20 400	0	..	44 400	0	..	44 400	0	44 400
Stevedoring	275 735	3 731	..	596 957	4 948	..	596 957	3 866	595 333
Load leg cost[c], FIO[d] terms[b]	607 104	..	..	922 838	..	..	822 573	..	580 336
Break even revenue required per tonne[b]	8.93	..	..	6.24	..	..	5.56	..	3.92

a. Nautical miles.
b. Australian dollars.
c. Incorporates a share of ballast leg costs, the share being determined by relative load leg distances.
d. Free in and out terms, that is, excludes stevedoring costs.
.. Not applicable.

Source BTCE estimates.

If the newbuilding shuttle service cases 1(i) and 1(ii) are compared, a significant saving through size economies resulting from the 150 000 dwt carrier is evident. The difference of just under $A4 in revenue required per tonne of coal on the load leg, represents a 31 per cent decrease in revenue required per tonne. When cases 1(ii) and 1(iii) are compared, however, it can be seen that another $A1.09 savings per cargo-tonne can be made on the first load leg to port B (4500 nautical miles), if a small triangulation route is adopted (as shown) in which the ballast leg costs are proportionately spread over the two cargo legs.

For the shuttle service cases employing 5-year old ships 1(iv) and 1(v), there is a smaller saving (less than $A3 per revenue tonne, or 30 per cent) available through size economies. Similarly, the additional saving resulting from the small triangulation route is smaller ($A0.68 per revenue tonne) than that estimated for new ships. The absolute revenues required per tonne on the first and second load legs of the triangulation are 24 and 23 per cent less respectively for the older ships in comparison with the new.

Pertaining to size economies, it is interesting to note that in the 1973 to 1983 period, based on data published by Drewry Shipping Consultants (1984), real operating costs per dwt have increased more for Handy-sized bulk ships than for the increasingly popular Panamax vessels. This result lends weight to the conclusion that economies of size enjoyed by larger vessels, Panamax and greater, are improving over time. Over the same period, however, representative real 1-year time charter rates have not only fallen, but have fallen more for the larger Panamax ships than for the Handy-sized vessels, a result which appears to underline the lack of relationship between freight rate and operating cost trends, at least over this 11-year period.

CASE 2 - LARGE TRIANGULATION

This case has some similarities to Case 1 except that the triangulation is carried out on a global scale. Six voyage types are compared:

(i) A new Australian-crewed ship of 150 000 dwt carries 147 000 tonnes of coal or other minerals from Port A to Port B over a voyage length of 10 000 nautical miles. It discharges its load and then takes on 147 000 tonnes of iron ore or other minerals and carries it to Port C over a voyage length of 11 000 nautical miles. Finally, it returns in ballast to Port A over a distance of 4500 nautical miles.

(ii) This is the same as (i) except that the new vessel is crewed under FOC conditions.

(iii) A new FOC ship of 150 000 dwt carries 147 000 tonnes of coal or other minerals from Port A to Port B and returns in ballast.

(iv) This is identical to (i) except that the vessel is 5 years old.

(v) This is identical to (ii) except that the vessel is 5 years old.

(vi) This is identical to (iii) except that the vessel is 5 years old.

In voyage types (i), (ii), (iv) and (v), the cost of the ballast leg is allocated to the two cargo carrying legs in proportion to the lengths of these cargo carrying legs. Other assumptions are given in Table 10.4.

The results of the analysis are presented in Tables 10.5 and 10.6. It is shown that a new Australian-crewed ship would be more expensive than an equivalent FOC ship undertaking an identical voyage. On the other hand, a new Australian-crewed ship is $A4.20 or 25 per cent cheaper than an equivalent FOC ship running a shuttle service on the first loaded leg. Similar results were obtained for the second-hand carrier simulations. On both load legs of the triangulation, the potential savings achievable with the 5-year old vessels are in the range of 25 to 29 per cent in comparison with identical shipping tasks performed by new carriers of the same size.

TABLE 10.4 ASSUMPTIONS APPLICABLE TO CASE 2 - LARGE TRIANGULATION

Voyage or cost parameter	*Assumed value*
Port A	
Loading rate	8000 tonnes per hour
Wharfage charges	$A0.20 per revenue tonne
Port B	
Discharge rate	3000 tonnes per hour
Loading rate	10 000 tonnes per hour
Wharfage charges	$A0.10 per revenue tonne
Port C	
Discharge rate	4000 tonnes per hour
Wharfage charges	$A0.10 per revenue tonne

Sources Gubbins (1986). BTCE estimates.

TABLE 10.5 SUMMARY OF COSTS FOR CASE 2 - LARGE TRIANGULATION - NEWBUILDINGS

Voyage parameter	*Case 2 (i) Ore carrier/150 000 dwt/AUS*			*Case 2 (ii) Ore carrier/150 000 dwt/FOC*			*Case 2 (iii) Ore carrier/150 000 dwt/FOC*		
	Leg 1	*Leg 2*	*Leg 3*	*Leg 1*	*Leg 2*	*Leg 3*	*Leg 1*	*Leg 2*	*Leg 3*
Load (tonnes)	147 000	147 000	0	147 000	147 000	0	147 000	0	..
Commodity	Coal	Iron Ore	Ballast	Coal	Iron Ore	Ballast	Coal	Ballast	..
Distance[a]	10 000	11 000	4 500	10 000	11 000	4 500	10 000	10 000	..
Cost component[b]									
Capital	748 796	801 211	236 095	748 796	801 211	236 095	748 796	519 927	..
Fuel	313 823	344 824	142 305	313 823	344 824	142 305	313 823	313 382	..
Crew	261 749	280 071	108 497	89 306	95 558	37 018	89 306	81 521	..
Other	107 178	114 680	43 677	109 600	117 270	44 680	109 600	98 393	..
Port	62 646	27 794	50 735	62 646	27 794	50 735	62 646	50 735	..
Wharfage	44 100	14 700	0	44 100	14 700	0	44 100	0	..
Stevedoring	597 373	598 300	4 252	597 373	598 300	4 252	597 373	9 364	..
Load leg cost[c], FIO[d] terms[b]	1815 106	1887 775	..	1611 525	1668 936	..	2432 229	..	..
Break even revenue required per tonne[b]	12.35	12.84	..	10.96	11.35	..	16.55	..	..

a. Nautical miles.
b. Australian dollars.
c. Incorporates a share of ballast leg costs, the share being determined by relative load leg distances.
d. Free in and out terms, that is, excludes stevedoring costs.
.. Not applicable.

Note If the Australian crew level in Case 2(i) is reduced from 26 to 21 and further to 18, break even revenue required per tonne for both legs will be lowered by 4 per cent and 8 per cent respectively.

Source BTCE estimates.

TABLE 10.6 SUMMARY OF COSTS FOR CASE 2 - LARGE TRIANGULATION - 5-YEAR OLD VESSELS

Voyage parameter	*Case 2 (iv) Ore carrier/150 000 dwt/AUS*			*Case 2 (v) Ore carrier/150 000 dwt/FOC*			*Case 2 (vi) Ore carrier/150 000 dwt/FOC*		
	Leg 1	*Leg 2*	*Leg 3*	*Leg 1*	*Leg 2*	*Leg 3*	*Leg 1*	*Leg 2*	*Leg 3*
Load (tonnes)	147 000	147 000	0	147 000	147 000	0	147 000	0	..
Commodity	Coal	Iron ore	Ballast	Coal	Iron ore	Ballast	Coal	Ballast	..
Distance[a]	10 000	11 000	4 500	10 000	11 000	4 500	10 000	10 000	..
Cost component[b]									
Capital	313 568	335 518	103 661	313 568	335 518	103 661	313 568	228 281	..
Fuel	364 882	400 951	165 490	364 882	400 951	165 490	364 882	364 441	..
Crew	261 749	280 071	108 497	89 306	95 558	37 018	89 306	81 521	..
Other	96 202	102 935	39 612	98 624	105 526	40 615	98 624	89 440	..
Port	62 646	27 794	50 735	62 646	27 794	50 735	62 646	50 735	..
Wharfage	44 100	14 700	0	44 100	14 700	0	44 100	0	..
Stevedoring	598 905	599 984	4 948	598 905	599 984	4 948	598 905	10 985	..
Load leg cost[c], FIO[d] terms[b]	1366 002	1407 109	..	1162 421	1188 271	..	1787 544	..	..
Break even revenue required per tonne[b]	9.29	9.57	..	7.91	8.08	..	12.16	..	..

a. Nautical miles.
b. Australian dollars.
c. Incorporates a share of ballast leg costs, the share being determined by relative load leg distances.
d. Free in and out terms, that is, excludes stevedoring costs.
.. Not applicable.

Source BTCE estimates.

CASE 3 - TWO-PORT LOADING

In Chapter 3 it was shown that 62 per cent of Australia's grain exports in 1985-86 were transported in ships of less than 40 000 dwt. Australia's major competitors for grain exports tend to use larger ships for their exports. Restrictions in some grain exporting ports prevent the use of larger ships or, alternatively, require that larger ships in the Panamax range partially load at a restricted port and top-up at a less restricted port. This case compares the cost of six hypothetical options which illustrate two-port loading:

(i) A 30 000 dwt ship is loaded with 28 000 tonnes of grain at the restricted port and sails direct to the discharge port over a voyage length of 6500 nautical miles. The ship then returns in ballast.

(ii) The same as (i) except that it is assumed there are no draught restrictions and that a 70 000 dwt ship, loaded with 63 000 tonnes of grain, is used.

(iii) A 70 000 dwt ship loads to 38 000 tonnes at the restricted port; sails 300 nautical miles to a top-up port where it completes loading to 63 000 tonnes and then sails 6500 nautical miles to a discharge port. The ship then returns in ballast.

(iv) This is identical to (i) except that the vessel is 5 years old.

(v) This is identical to (ii) except that the vessel is 5 years old.

(vi) This is identical to (iii) except that the vessel is 5 years old.

All vessels are assumed to operate under FOC conditions. Other assumptions relevant to these two-port loading cases are set out in Table 10.7 and the results of the analysis are summarised in Tables 10.8 and 10.9.

The use of two-port loading in the newbuildings example causes revenue required per tonne (to break even on the load legs) to be raised by $A0.92. Despite this additional cost it is still considerably less expensive than using a smaller vessel (30 000 dwt) which can fully load at the restricted port. The $A0.92 per tonne is an indication of the savings that could be made by improving the restricted port.

However, such savings could only be realised if the discharge ports served on this trade could also accommodate the larger ships.

For the second-hand vessels a similar story applies. The savings in revenue required per tonne is smaller at $A0.76.

TABLE 10.7 ASSUMPTIONS APPLICABLE TO CASE 3 - TWO-PORT LOADING

Voyage or cost component	*Assumed value*
Restricted loading port	
Loading rate	1000 tonnes per hour
Wharfage charges	$A1.00 per revenue tonne
Top-up port	
Loading rate	1000 tonnes per hour
Wharfage charges	$A1.50 per revenue tonne
Discharge port	
Discharge rate	400 tonnes per hour
Wharfage charges	$A0.50 per revenue tonne

Source BTCE estimates.

TABLE 10.8 SUMMARY OF COSTS FOR CASE 3 - TWO-PORT LOADING - NEWBUILDINGS

Voyage parameter	*Case 3 (i)* *Grain carrier/30 000 dwt/FOC*			*Case 3 (ii)* *Grain carrier/70 000 dwt/FOC*			*Case 3 (iii)* *Grain carrier/70 000 dwt/FOC*		
	Leg 1	*Leg 2*	*Leg 3*	*Leg 1*	*Leg 2*	*Leg 3*	*Leg 1*	*Leg 2*	*Leg 3*
Load (tonnes)	28 000	0	..	63 000	0	..	38 000	63 000	0
Commodity	Grain	Ballast	..	Grain	Ballast	..	Grain	Grain	Ballast
Distance[a]	6 500	6 500	..	6 500	6 500	..	300	6 500	6 500
Cost component[b]									
Capital	221 171	137 848	..	428 012	218 093	..	39 929	404 400	218 093
Fuel	118 968	118 303	..	167 208	165 713	..	9 700	166 960	165 713
Crew	64 929	53 201	..	79 589	53 201	..	7 425	75 198	53 201
Other	48 319	39 154	..	75 125	49 531	..	7 009	70 980	49 531
Port	13 931	11 272	..	30 170	24 426	..	30 170	13 402	24 426
Wharfage	42 000	0	..	94 500	0	..	75 500	31 500	0
Stevedoring	199 539	3 524	..	445 979	4 947	..	315 288	130 974	4 947
Load leg cost[c], FIO[d] terms[b]	869 096	..	..	1 385 568	..	..	1 443 137		..
Break even revenue required per tonne[b]	31.04	..	..	21.99	..	..	22.91		..

a. Nautical miles.
b. Australian dollars.
c. Incorporates a share of ballast leg costs, the share being determined by relative load leg distances.
d. Free in and out terms, that is, excludes stevedoring costs.
.. Not applicable.

Source BTCE estimates.

TABLE 10.9 SUMMARY OF COSTS FOR CASE 3 - TWO-PORT LOADING - 5-YEAR OLD VESSELS

Voyage parameter	*Case 3 (iv)* *Grain carrier/30 000 dwt/FOC*			*Case 3 (v)* *Grain carrier/70 000 dwt/FOC*			*Case 3 (vi)* *Grain carrier/70 000 dwt/FOC*		
	Leg 1	*Leg 2*	*Leg 3*	*Leg 1*	*Leg 2*	*Leg 3*	*Leg 1*	*Leg 2*	*Leg 3*
Load (tonnes)	28 000	0	..	63 000	0	..	38 000	63 000	0
Commodity	Grain	Ballast	..	Grain	Ballast	..	Grain	Grain	Ballast
Distance[a]	6 500	6 500	..	6 500	6 500	..	300	6 500	6 500
Cost component[b]									
Capital	68 659	44 704	..	160 209	83 491	..	14 946	151 370	83 491
Fuel	125 614	124 949	..	181 027	179 532	..	10 488	180 779	179 532
Crew	64 929	53 201	..	79 589	53 201	..	7 425	75 198	53 201
Other	42 724	34 891	..	66 358	44 118	..	6 191	62 695	44 118
Port	13 931	11 272	..	30 170	24 426	..	30 170	13 402	24 426
Wharfage	42 000	0	..	94 500	0	..	75 500	31 500	0
Stevedoring	199 738	3 724	..	446 394	5 361	..	315 311	131 389	5 361
Load leg cost[c], FIO[d] terms[b]	626 874	..	..	996 621	..	..	1 044 432		..
Break even revenue required per tonne[b]	22.39	..	..	15.82	..	..	16.58		..

a. Nautical miles.
b. Australian dollars.
c. Incorporates a share of ballast leg costs, the share being determined by relative load leg distances.
d. Free in and out terms, that is, excludes stevedoring costs.
.. Not applicable.

Source BTCE estimates.

CASE 4 - SELF-UNLOADERS

This case compares the cost of 12 hypothetical options:

(i) A 70 000 dwt Australian-crewed self-unloader loads 68 000 tonnes of coal at port A, at a loading rate of 8000 tonnes per hour and sails direct to port B (a distance of 6000 nautical miles) where it self-unloads its cargo at a discharge rate of 7000 tonnes per hour. The vessel then returns direct to port A carrying ballast.

(ii) A 30 000 dwt FOC-crewed self-unloader loads 28 000 tonnes of coal at port A, at a loading rate of 8000 tonnes per hour and sails direct to port B (a distance of 6000 nautical miles) where it self-unloads its cargo at a discharge rate of 6000 tonnes per hour. The vessel then returns direct to port A carrying ballast.

(iii) This is identical to (ii) except that the self-unloader sails direct from port A to port C, a distance of 500 nautical miles.

(iv) This is identical to (i) except that the vessel is a conventional bulk carrier which has its coal unloaded at port B at a rate of 3000 tonnes per hour.

(v) This is identical to (ii) except that the vessel is a conventional bulk carrier which has its coal unloaded at port B at a rate of 3000 tonnes per hour.

(vi) This is identical to (v) except that the discharge port is port C, a distance of 500 nautical miles from port A.

(vii) This is identical to (i) except that the vessel is 5 years old.

(viii) This is identical to (ii) except that the vessel is 5 years old.

(ix) This is identical to (iii) except that the vessel is 5 years old.

(x) This is identical to (iv) except that the vessel is 5 years old.

(xi) This is identical to (v) except that the vessel is 5 years old.

(xii) This is identical to (vi) except that the vessel is 5 years old.

Ports A, B and C are assumed to make wharfage charges of $A0.20, $A0.10 and $A0.20 per revenue tonne respectively. Note that the discharge rates vary with the size of self-unloader.

The capital cost of a self-unloading bulk carrier has been set at 20 per cent above the capital cost of an equivalently sized and powered conventional bulk carrier. This assumption is consistent with that made in Chapter 5 and, of course, implies vessel insurance, repairs and maintenance, as well as administration charges, will also be 20 per cent greater than for an equivalent carrier.

The results of these 12 hypothetical options, given the above assumptions, are set out in Tables 10.10 to 10.13.

A comparison of the newbuildings' cost estimates shows the potential savings that can be made with these special carriers and, in particular, on short hauls as cases 4(iii) and 4(vi) demonstrate. On short hauls the self-unloaders make these substantial savings because the additional capital cost of the self-unloading capability is far outweighed by:

- the elimination of wharfage and stevedoring charges at the unloading port;
- the substantial reduction in port charges at the unloading port; and
- the savings in capital, crew and other costs incurred per voyage because self-unloading rates are faster than normal handling rates, thereby reducing the total voyage duration.

On longer hauls, the advantages of self-unloaders are greatly reduced as the extra capital costs tend to outweigh the savings at the unloading port, and such advantages can even be eliminated altogether, as can be seen with cases 4(i) and 4(iv) as well as cases 4(ii) and 4(v).

With the second-hand self-unloaders, the results were in the same direction, although with variable magnitudes. The potential savings on the short-haul small vessel configuration amounted to 10 per cent compared with 5 per cent with new vessels. However, as self unloaders tend to be built for specific applications, they are less likely to be available on the second-hand market than conventional dry bulk carriers.

The example suggests that self-unloading ships can be cost effective on longer routes if they allow the use of larger ships. This might occur when the maximum size of conventional bulk carriers is limited

TABLE 10.10 SUMMARY OF COSTS FOR CASE 4 - SELF-UNLOADERS - NEWBUILDINGS

	Case 4 (i) Self-unloader/70 000 dwt/AUS		*Case 4 (ii) Self-unloader/30 000 dwt/FOC*		*Case 4 (iii) Self-unloader/30 000 dwt/FOC*	
	Leg 1	*Leg 2*	*Leg 1*	*Leg 2*	*Leg 1*	*Leg 2*
Load (tonnes)	68 000	0	28 000	0	28 000	0
Commodity	Coal	Ballast	Coal	Ballast	Coal	Ballast
Distance[a]	6 000	6 000	6 000	6 000	500	500
Cost component[b]						
Capital	330 798	241 810	204 786	152 838	22 874	14 466
Fuel	153 230	153 111	109 360	109 307	10 398	10 345
Crew	150 239	144 070	50 099	49 155	5 596	4 652
Other	52 771	49 843	40 738	39 483	4 550	3 737
Port	20 597	20 597	9 499	9 499	9 499	9 499
Wharfage	13 600	0	5 600	0	5 600	0
Stevedoring	145 144	0	62 514	0	56 617	0
Load leg cost[c], FIO[d] terms[b]	1 330 666	..	780 364	..	101 216	..
Break even revenue required per tonne[b]	19.57	..	27.87	..	3.61	..

a. Nautical miles.
b. Australian dollars.
c. Incorporates a share of ballast leg costs, the share being determined by relative load leg distances.
d. Free in and out terms, that is, excludes stevedoring costs.
.. Not applicable.

Source BTCE estimates.

TABLE 10.11 SUMMARY OF COSTS FOR CASE 4 - BULK CARRIERS - NEWBUILDINGS

	Case 4 (iv) Bulk carrier/70 000 dwt/AUS		*Case 4 (v) Bulk carrier/30 000 dwt/FOC*		*Case 4 (vi) Bulk carrier/30 000 dwt/FOC*	
	Leg 1	*Leg 2*	*Leg 1*	*Leg 2*	*Leg 1*	*Leg 2*
Load (tonnes)	68 000	0	28 000	0	28 000	0
Commodity	Coal	Ballast	Coal	Ballast	Coal	Ballast
Distance[a]	6 000	6 000	6 000	6 000	500	500
Cost component[b]						
Capital	283 714	201 508	172 492	127 365	20 899	12 055
Fuel	153 315	153 111	109 391	109 307	10 429	10 345
Crew	154 625	144 070	50 638	49 155	6 135	4 652
Other	48 367	44 430	37 684	36 175	4 565	3 424
Port	30 170	24 426	13 931	11 272	13 931	11 272
Wharfage	20 400	0	8 400	0	8 400	0
Stevedoring	276 575	4 571	115 258	3 256	112 310	308
Load leg cost[c], FIO[d] terms[b]	1 258 136	..	725 810	..	106 107	..
Break even revenue required per tonne[b]	18.50	..	25.92	..	3.79	..

a. Nautical miles.
b. Australian dollars.
c. Incorporates a share of ballast leg costs, the share being determined by relative load leg distances.
d. Free in and out terms, that is, excludes stevedoring costs.
.. Not applicable.

Source BTCE estimates.

TABLE 10.12 SUMMARY OF COSTS FOR CASE 4 - SELF-UNLOADERS - 5-YEAR OLD VESSELS

	Case 4 (vii) Self-unloader/70 000 dwt/AUS		*Case 4 (viii) Self-unloader/30 000 dwt/FOC*		*Case 4 (ix) Self-unloader/30 000 dwt/FOC*	
	Leg 1	*Leg 2*	*Leg 1*	*Leg 2*	*Leg 1*	*Leg 2*
Load (tonnes)	68 000	0	28 000	0	28 000	0
Commodity	Coal	Ballast	Coal	Ballast	Coal	Ballast
Distance[a]	6 000	6 000	6 000	6 000	500	500
Cost component[b]						
Capital	123 820	92 570	63 572	49 566	7 100	4 691
Fuel	165 999	165 880	115 501	115 448	10 980	10 927
Crew	150 239	144 070	50 099	49 155	5 596	4 652
Other	45 994	43 842	35 557	34 758	3 806	3 289
Port	20 597	20 597	9 499	9 499	9 499	9 499
Wharfage	13 600	0	5 600	0	5 600	0
Stevedoring	145 910	0	62 883	0	56 653	0
Load leg cost[c], FIO[d] terms[b]	987 208	..	538 254	..	75 639	..
Break even revenue required per tonne[b]	14.52	..	19.22	..	2.70	..

a. Nautical miles.
b. Australian dollars.
c. Incorporates a share of ballast leg costs, the share being determined by relative load leg distances.
d. Free in and out terms, that is, excludes stevedoring costs.
.. Not applicable.

Source BTCE estimates.

TABLE 10.13 SUMMARY OF COSTS FOR CASE 4 - BULK CARRIERS - 5-YEAR OLD VESSELS

	Case 4 (x) Bulk carrier/70 000 dwt/AUS		*Case 4 (xi) Bulk carrier/30 000 dwt/FOC*		*Case 4 (xii) Bulk carrier/30 000 dwt/FOC*	
	Leg 1	*Leg 2*	*Leg 1*	*Leg 2*	*Leg 1*	*Leg 2*
Load (tonnes)	68 000	0	28 000	0	28 000	0
Commodity	Coal	Ballast	Coal	Ballast	Coal	Ballast
Distance[a]	6 000	6 000	6 000	6 000	500	500
Cost component[b]						
Capital	106 197	77 142	53 547	41 305	6 488	3 909
Fuel	166 084	165 880	115 532	115 448	11 011	10 927
Crew	154 625	144 070	50 638	49 155	6 135	4 652
Other	42 555	39 429	33 320	32 237	4 037	3 051
Port	30 170	24 426	13 931	11 272	13 931	11 272
Wharfage	20 400	0	8 400	0	8 400	0
Stevedoring	276 958	4 954	115 442	3 441	112 328	326
Load leg cost[c], FIO[d] terms[b]	970 978	..	524 785	..	83 813	..
Break even revenue required per tonne[b]	14.28	..	18.74	..	2.99	..

a. Nautical miles.
b. Australian dollars.
c. Incorporates a share of ballast leg costs, the share being determined by relative load leg distances.
d. Free in and out terms, that is, excludes stevedoring costs.
.. Not applicable.

Source BTCE estimates.

by draught restrictions. Self-unloaders can avoid this limitation by discharging their cargo into smaller ships or barges in deeper water outside the port. Comparison between cases 4(i) and 4(v) illustrate the savings ($6.35 per tonne) that could be available through this operating strategy. Some of these savings would be offset by the cost of moving the cargo from the self-unloaidng ship into the destination port.

SUMMARY

This chapter has applied the cost model developed in earlier chapters to particular operating strategies. These applications illustrate the operating cost advantage of developing triangular routes which reduce the proportion of time a ship is sailing on non-revenue producing ballast voyages. The results indicate that an Australian ship operating a triangular route can be competitive with a FOC ship of the same size operating a shuttle service on one of the load legs.

The use of two-port loading is shown to be considerably less costly than operating a small vessel which can fully load at the draught restricted port. In the example chosen, the difference was approximately $9 per tonne. If the draught-restricted port were deepened to allow larger ships, which previously required topping-up at a second port to be fully loaded, costs would be reduced further by 92 cents per tonne compared to two-port loading costs.

The final example indicates the cost savings which can be achieved through the use of self-unloading ships. The savings mainly arise through the reduction in stevedoring and port costs in the discharge port. Self-unloaders have most of their applications on shorter routes. On longer routes they can also be cost effective if they allow the substitution of larger ships for smaller ones.

CHAPTER 11 CONCLUSIONS

This study has examined the major descriptors of the supply-side of dry bulk shipping which, in combination with demand factors, influence freight rates in the short-run, and the size and composition of the bulk shipping fleet in the longer-run. The broad supply-side aspects of the bulk shipping industry analysed in this Paper have been:

- the distributions of the world dry bulk shipping fleet and that which visited Australia during 1985-86;
- technological change and its impact on the existing and future fleets;
- the operating cost structure of dry bulk shipping in theory, including the development of a comprehensive cost model; and
- the operating cost structure of dry bulk shipping in practice.

Within the scope of these four categories, a comprehensive range of issues have been examined. A number of these issues are particularly relevant to Australian shippers and shipowners.

Australia is generally well served by the bulk shipping industry. On average, the bulk ships visiting Australia are large and relatively new compared to ships in the world fleet. Export commodities served by these large ships benefit from the economies of size and the lower operating costs that newer ships generally experience. Grain exports are the major exception. Over 60 per cent of Australian grain exports in 1985-86 were carried in bulk ships of less than 40 000 dwt. During 1985 only 36 per cent of total world grain trade was carried in ships of this size. The use of small vessels in Australian grain trades is partially explained by the number of draught-restricted grain ports. Restrictions in destination ports may also provide some explanation but this point was not investigated. Whatever the explanation, the result is that shipping costs for Australian grain exports are higher than those experienced by major competitors in the grain trade.

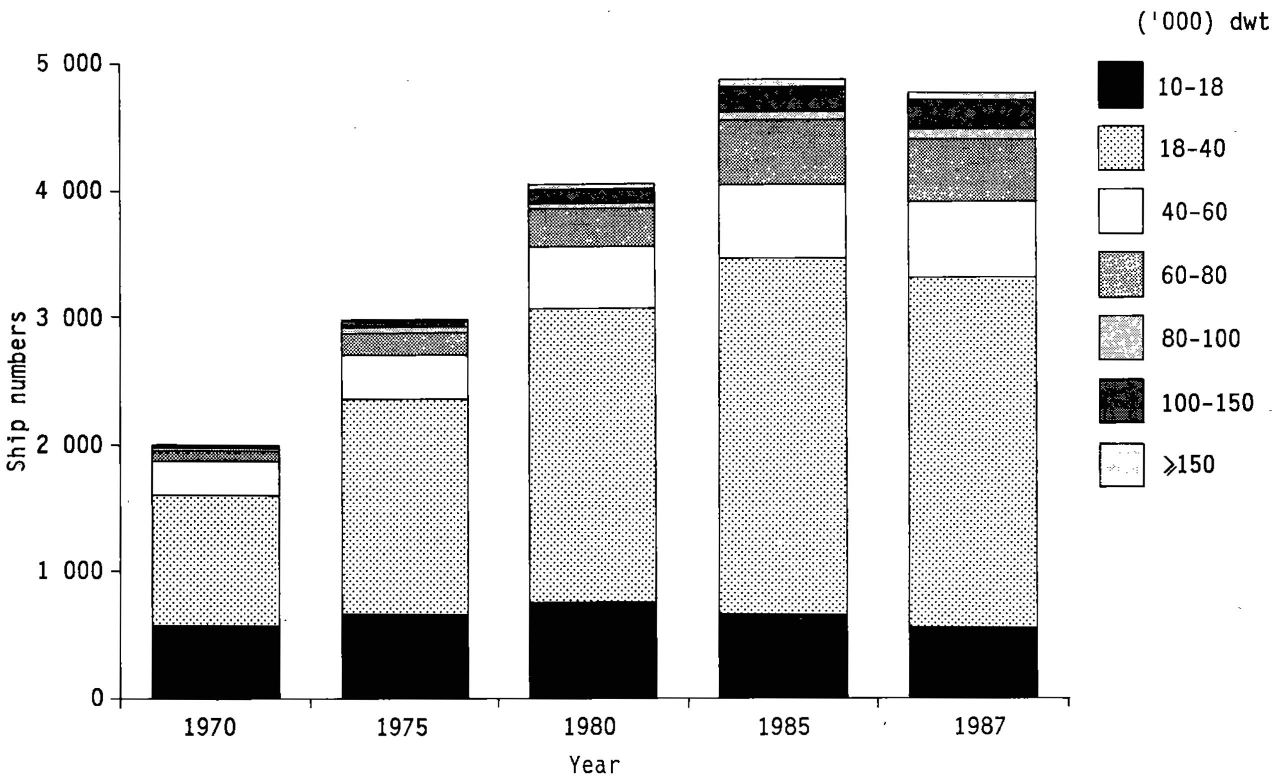
Australian crew costs per berth are reasonably consistent with costs in other advanced maritime countries. Comparisons are sensitive to exchange rate variations. However, the number of berths on new Australian ships are significantly higher than on new ships in other developed countries. Reductions in crew sizes have been made through implementation of the MIDC recommendations. While crew costs for new ships rank below capital costs and fuel costs (on larger ships) in magnitude, they represent the cost item most susceptible to control by shipowners. It is in this area where cost differentials between flags are most evident. For this reason, it is important that the gap between Australian crew costs and those experienced in other developed countries be narrowed if Australian shipping is to become more competitive.

In many ways technological developments of bulk ships are favourable to a competitive Australian industry. The average size of bulk ships has increased and there has also been a trend to broader, shallower ships that allow larger ships to use draught-restricted ports. The incentive to use larger bulk ships, of course, lies in the economies of size that can be attained by their use. This is most evident for crew costs which are for the most part largely independent of ship size. Thus, higher Australian crew costs are less of a disadvantage if large ships can be used.

Triangular routes which involve two-load legs are shown to offer lower costs than a shuttle service over one of the load legs. This cost reduction arises principally because the proportion of time the ship is in ballast is reduced. Australian shipowners have taken advantage of this approach by combining coastal and international transport tasks. BHP ships are the major example where this concept has not only reduced the proportion of ballast voyage time but has also allowed the use of larger ships.

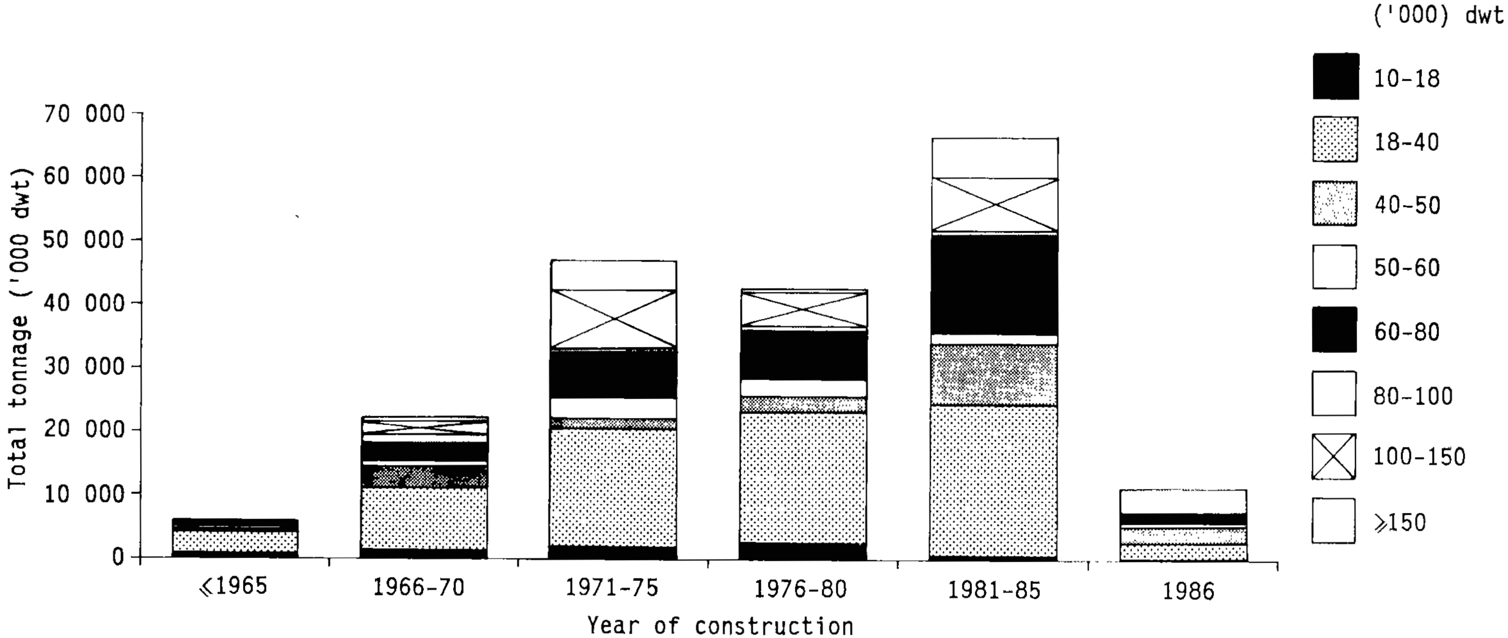
Finally, the Paper has indicated that there are potential advantages in the use of self-unloading ships. However, they have higher capital costs than conventional bulk carriers and their introduction requires careful analysis to ensure their profitability. Because self-unloaders require changed working arrangements, their introduction also has implications for industrial relations.

APPENDIX I WORLD BULK FLEET FIGURES



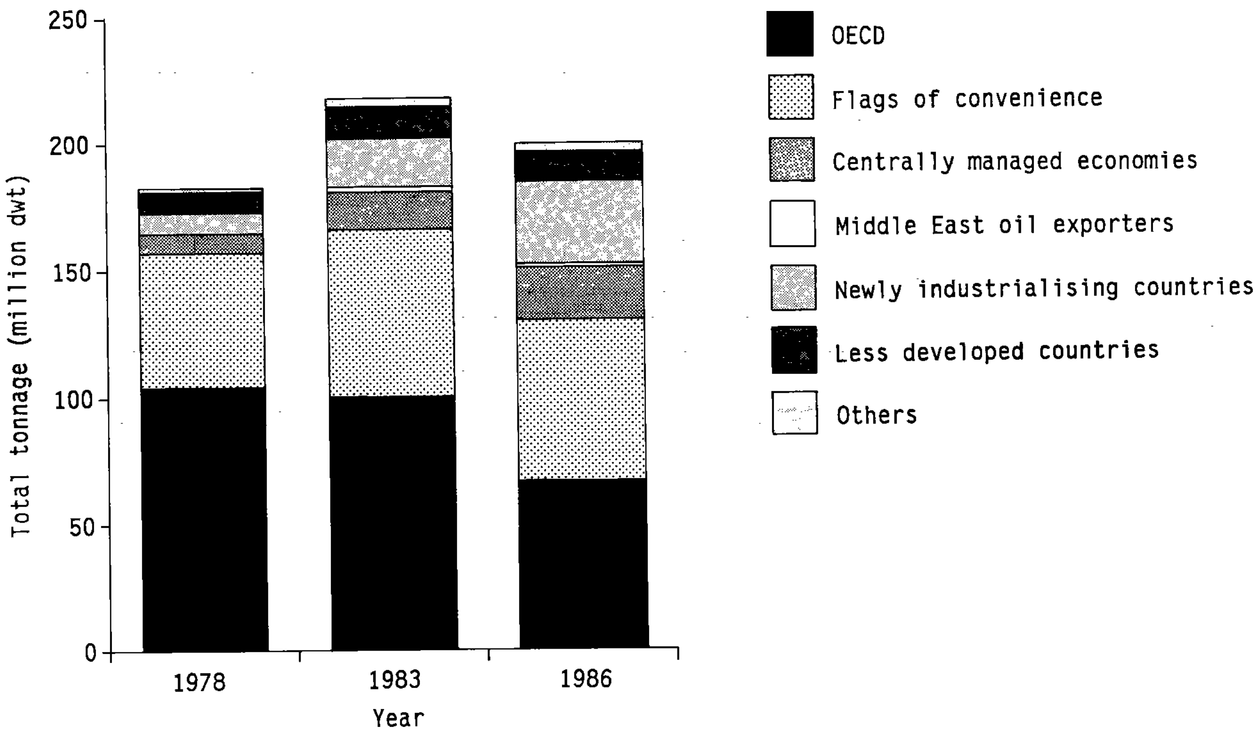
Sources Fearnleys (1976, 1987). BTCE estimates.

Figure I.1 Development of the size distribution of the world bulk fleet



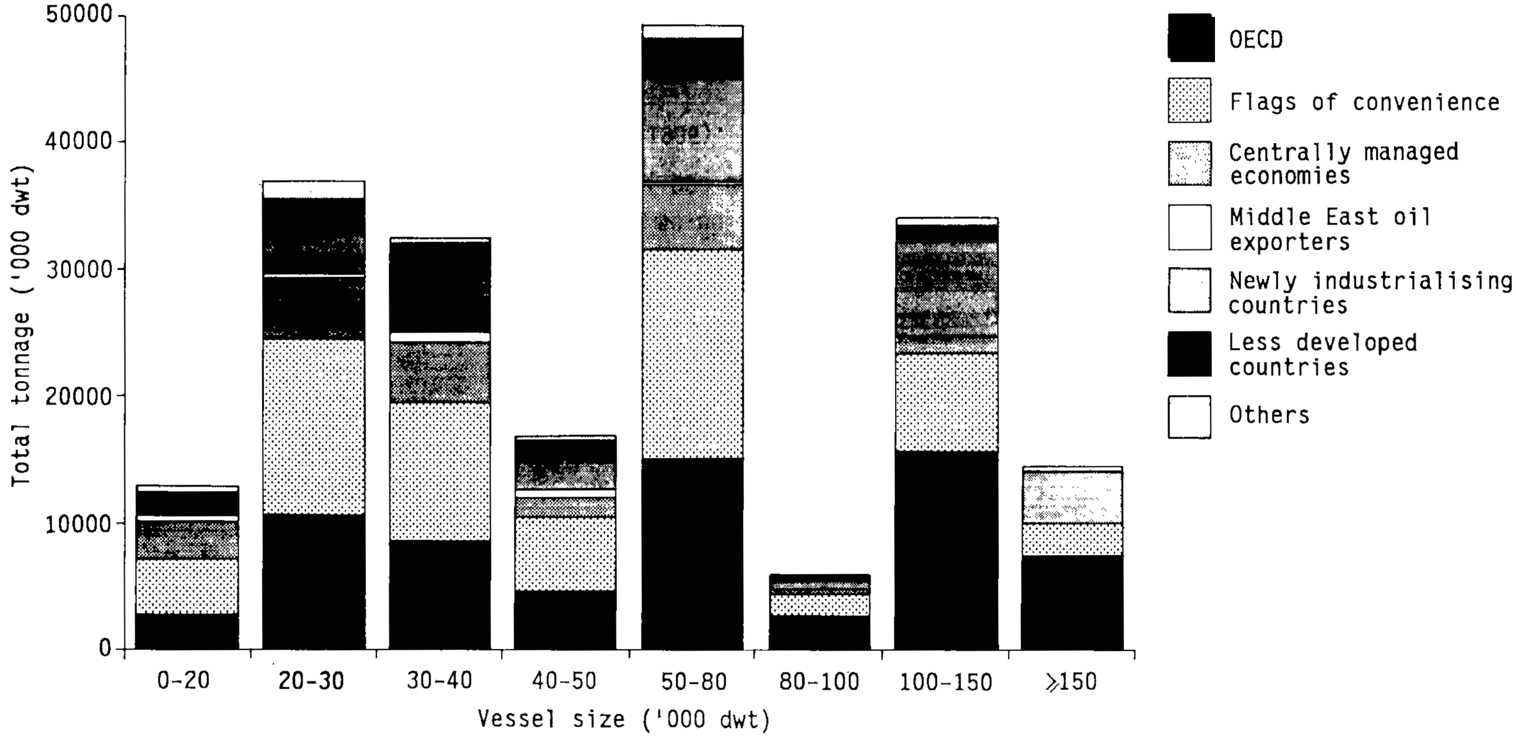
Sources Fearnleys (1987). BTCE estimates.

Figure I.2 Size-age distribution of the world bulk fleet, January 1987



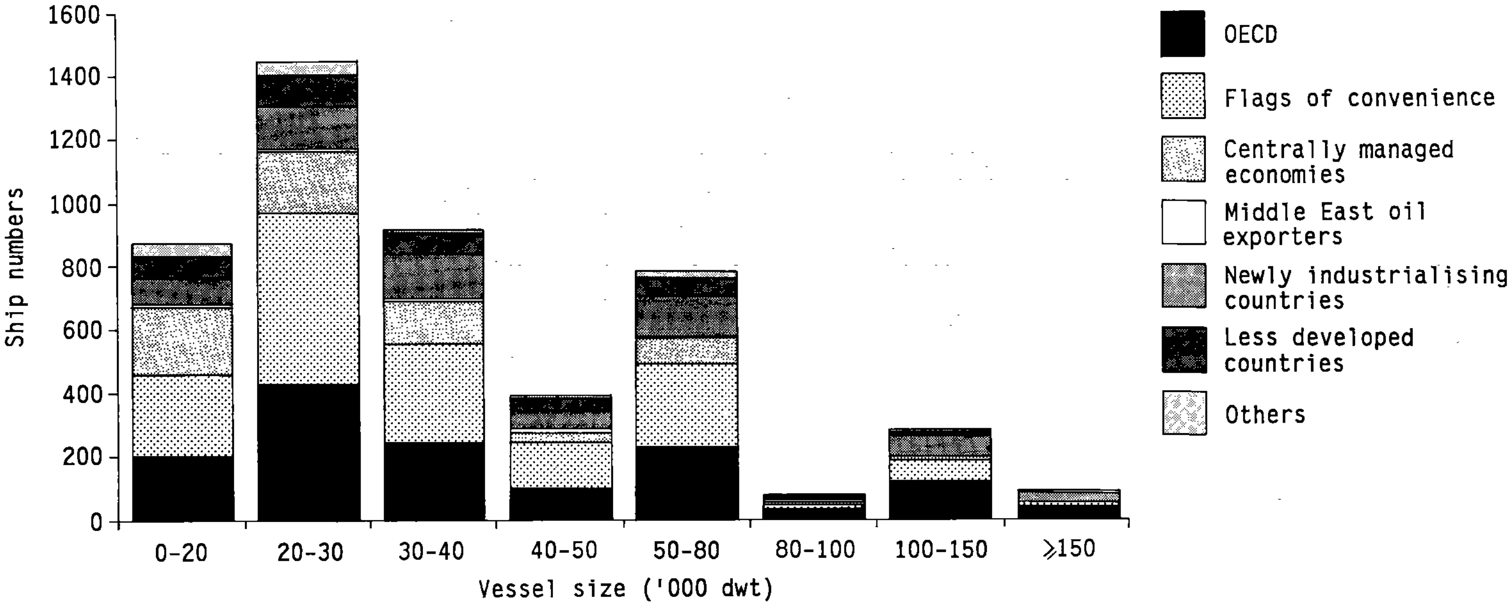
Sources The Bristish Maritime Charitable Foundation (1986). Lloyd's Register of Shipping (1986). BTCE estimates.

Figure I.3 Deadweight tonnage by flag, world bulk fleet, 1978, 1983 and 1986



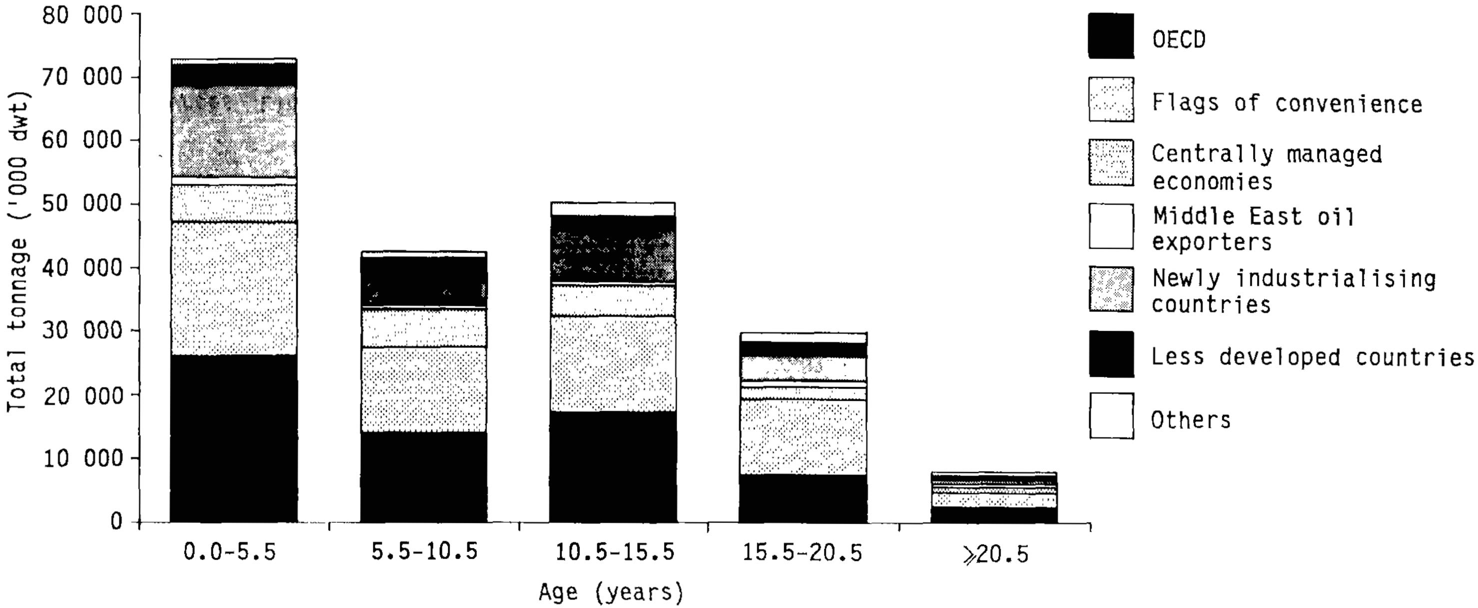
Sources Lloyd's Register of Shipping (1986). BTCE estimates.

Figure I.4 Deadweight tonnage by flag vessel by size, world bulk fleet, June 1986



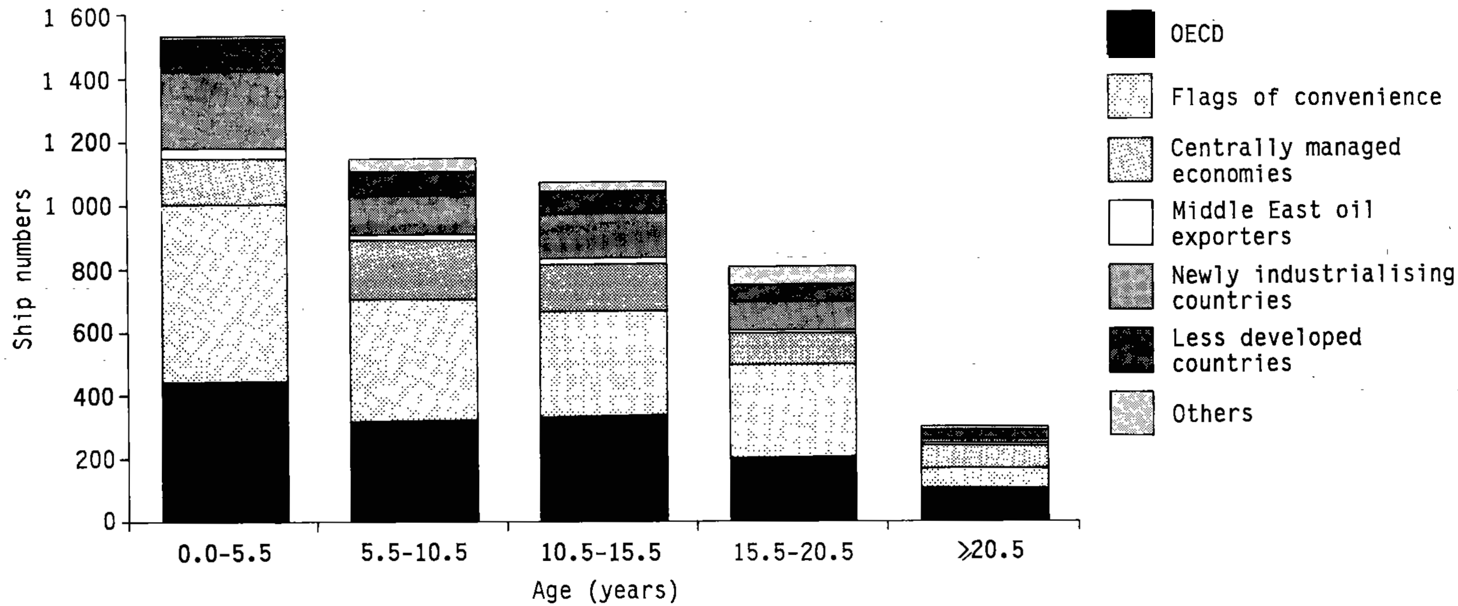
Sources Lloyd's Register of Shipping (1986). BTCE estimates.

Figure I.5 Ship numbers by flag by vessel size, world bulk fleet, June 1986



Sources Lloyd's Register of Shipping (1986). BTCE estimates.

Figure I.6 Deadweight tonnage by flag by age, world bulk fleet, June 1986



Sources Lloyd's Register of Shipping (1986). BTCE estimates.

Figure I.7 Ship numbers by flag by age, world bulk fleet, June 1986

APPENDIX II SHIP CHARACTERISTICS TABLES

TABLE II.1 SHIP CHARACTERISTICS, FOC AND NON-FOC SHIPS, 1985-86

	FOC ships	*Non-FOC ships*	*Total*
Bulk carriers			
Visitors	402	978	1 380
	(29.1)	(70.9)	(100.0)
Non-visitors	1 087	1 960	3 047
	(35.7)	(64.3)	(100.0)
Sub-total	1 489	2 938	4 427
	(33.6)	(66.4)	(100.0)
Ore-bulk-oil carriers			
Visitors	6	37	43
	(14.0)	(86.0)	(100.0)
Non-visitors	92	103	195
	(47.2)	(52.8)	(100.0)
Sub-total	98	140	238
	(41.2)	(58.8)	(100.0)
Ore carriers			
Visitors	6	38	44
	(13.6)	(86.4)	(100.0)
Non-visitors	28	112	140
	(20.0)	(80.0)	(100.0)
Sub-total	34	150	184
	(18.5)	(81.5)	(100.0)
Dry bulk ships			
Visitors	414	1 053	1 467
	(28.2)	(71.8)	(100.0)
Non-visitors	1 207	2 175	3 382
	(35.7)	(64.3)	(100.0)
Total	1 621	3 228	4 849
	(33.4)	(66.6)	(100.0)

Note Figures in parentheses are percentages.

Sources Lloyd's Register of Shipping (1986). BTCE estimates.

TABLE II.2 SHIP CHARACTERISTICS, AGE AND DEADWEIGHT TONNAGE, 1985-86

	Bulk carriers			*Ore-bulk-oil carriers*			*Ore carriers*		
	Visitors	*Non-visitors*	*Total*	*Visitors*	*Non-visitors*	*Total*	*Visitors*	*Non-visitors*	*Total*
					Age (years)				
Mean	7.0	11.0	9.8	11.9	10.8	11.0	11.8	20.3	18.3
Median	5.3	10.8	9.2	13.7	11.5	12.0	13.4	20.1	18.0
Mode	2.0	9.0	2.0	14.0	12.0	14.0	15.0	15.0	15.0
Standard deviation	5.3	6.6	6.5	5.4	5.2	5.2	5.7	6.2	7.1
Minimum	0.0	0.0	0.0	1.0	1.0	1.0	0.0	3.0	0.0
Maximum	27.0	63.0	63.0	19.0	20.0	20.0	21.0	36.0	36.0
					Deadweight tonnage				
Mean	50 321	33 371	38 663	115 428	92 835	96 917	117 375	30 005	50 898
Median	37 129	27 060	30 012	113 535	86 356	98 373	114 697	17 992	24 991
Standard deviation	37 156	19 816	27 615	38 452	30 616	33 244	45 795	37 462	54 362
Minimum	11 226	590	590	35 924	14 763	14 763	23 286	492	492
Maximum	221 119	255 489	255 489	166 753	174 107	174 107	195 765	263 659	263 659

Sources Lloyd's Register of Shipping (1986). BTCE estimates.

TABLE II.3 SHIP CHARACTERISTICS, POWER, SPEED AND FUEL CONSUMPTION, 1985-86

	Bulk carriers			*Ore-bulk-oil carriers*			*Ore carriers*		
	Visitors	*Non-visitors*	*Total*	*Visitors*	*Non-visitors*	*Total*	*Visitors*	*Non-visitors*	*Total*
				Maximum power (kilowatts)					
Mean	9 100	8 188	8 472	17 082	15 123	15 481	16 225	6 433	8 705
Median	8 616	8 354	8 355	16 117	14 920	15 441	17 181	4 921	7 386
Standard deviation	3 262	2 655	2 889	4 845	3 637	3 947	4 525	4 689	6 221
Minimum	1 119	325	325	6 825	4 774	4 774	7 161	174	174
Maximum	23 872	24 618	24 618	23 872	27 005	27 005	23 872	22 678	23 872
				Maximum speed (knots)					
Mean	14.6	14.8	14.7	15.3	15.1	15.2	14.7	13.7	13.9
Median	14.3	15.0	15.0	15.2	15.2	15.2	15.0	14.2	14.3
Mode	15.0	15.0	15.0	15.2	16.0	16.0	14.3	15.0	15.0
Standard deviation	0.9	1.0	1.0	0.7	0.9	0.8	0.7	1.9	1.7
Minimum	10.2	7.0	7.0	13.1	12.2	12.2	13.1	8.2	8.2
Maximum	18.1	19.0	19.0	16.2	19.3	19.3	16.0	17.0	17.0

TABLE II.3 (Cont.) SHIP CHARACTERISTICS, POWER, SPEED AND FUEL CONSUMPTION, 1985-86

	Bulk carriers			*Ore-bulk-oil carriers*			*Ore carriers*		
	Visitors	*Non-visitors*	*Total*	*Visitors*	*Non-visitors*	*Total*	*Visitors*	*Non-visitors*	*Total*
	Fuel consumption (tonnes per day)								
Mean	38.8	35.3	36.5	80.2	65.8	68.4	79.5	37.5	53.8
Median	35.2	35.0	35.0	78.1	64.2	68.0	74.4	32.3	49.2
Standard deviation	15.8	11.9	13.4	25.7	22.0	23.3	38.4	22.6	36.0
Minimum	15.3	2.0	2.0	29.2	29.2	29.2	33.0	7.1	7.1
Maximum	138.0	108.1	138.0	137.0	154.0	154.0	216.2	101.3	216.2

Sources Lloyd's Register of Shipping (1986). BTCE estimates.

TABLE II.4 SHIP CHARACTERISTICS, LENGTH, BREADTH AND DRAUGHT, 1985-86

	Bulk carriers			*Ore-bulk-oil carriers*			*Ore carriers*		
	Visitors	*Non-visitors*	*Total*	*Visitors*	*Non-visitors*	*Total*	*Visitors*	*Non-visitors*	*Total*
					Length (metres)				
Mean	198.27	182.02	187.10	262.68	249.67	252.02	260.32	164.76	187.21
Median	187.48	180.14	182.29	258.80	253.59	253.63	260.92	160.00	174.96
Standard deviation	37.42	30.54	33.69	28.47	23.41	24.85	34.05	54.23	64.53
Minimum	125.27	47.27	47.27	182.60	155.14	155.14	165.83	48.79	48.79
Maximum	314.87	328.57	328.57	304.82	303.30	304.82	313.67	324.01	324.01
					Breadth (metres)				
Mean	29.44	25.53	26.69	40.05	36.12	36.85	40.06	24.28	28.09
Median	28.35	24.41	25.91	40.85	37.82	37.83	40.55	22.55	24.86
Standard deviation	6.20	4.49	5.37	5.70	5.01	5.36	6.02	8.08	10.19
Minimum	19.52	9.15	9.15	32.03	21.34	21.34	23.80	11.30	11.30
Maximum	50.59	53.96	53.96	53.65	53.03	53.65	50.59	54.88	54.88

TABLE II.4 (Cont.) SHIP CHARACTERISTICS, LENGTH, BREADTH AND DRAUGHT, 1985-86

	Bulk carriers			*Ore-bulk-oil carriers*			*Ore carriers*		
	Visitors	*Non-visitors*	*Total*	*Visitors*	*Non-visitors*	*Total*	*Visitors*	*Non-visitors*	*Total*
	Draught (metres)								
Mean	11.61	10.54	10.87	15.70	14.82	14.98	15.08	9.14	10.57
Median	10.98	10.38	10.67	15.85	14.65	14.94	15.88	9.16	9.65
Standard deviation	2.23	1.64	1.91	1.91	1.80	1.85	2.57	3.22	3.99
Minimum	7.65	2.44	2.44	11.92	6.72	6.72	9.15	1.83	1.83
Maximum	19.81	19.53	19.81	18.31	19.21	19.21	17.99	20.42	20.42

Sources Lloyd's Register of Shipping (1986). BTCE estimates.

APPENDIX III

CHI-SQUARE TESTS

Chi-square tests were performed for the three vessel characteristics analysed in Chapter 3 - ship size (given by deadweight tonnage), age and flag. A brief description of these three analyses is given below, together with the results. It will be noted that all computed Chi-square values, except one, were statistically significant at the 5 per cent level, meaning that the world fleet size, age and flag distributions were significantly different, in a statistical sense, from the corresponding distributions of the 1985-86 port calls and visitors fleets.

Ship size

Assuming the world fleet numbers and tonnage distributions to be statistically expected, Chi-square values on 7 degrees of freedom were calculated using the aggregate percentage distributions of ship numbers and deadweight tonnage shown in the last row of Tables 3.2, 3.3, 3.4, 3.5, 3.6 and 3.7. The resulting Chi-square values for the ship numbers' distributions were therefore calculated as follows:

Total port calls fleet $$\chi^2_7 = \frac{(13.44 - 17.97)^2}{17.97} + \ldots + \frac{(3.61 - 1.73)^2}{1.73} = 12.33^*$$

Visitors fleet $$\chi^2_7 = \frac{(8.52 - 17.97)^2}{17.97} + \ldots + \frac{(4.36 - 1.73)^2}{1.73} = 16.95^{**}$$

The resulting Chi-square values for the tonnage distributions were calculated as follows:

Total port calls fleet $$\chi^2_7 = \frac{(4.21 - 6.51)^2}{6.51} + \ldots + \frac{(12.04 - 7.14)^2}{7.14} = 17.54^{**}$$

Visitors fleet $$\chi^2_7 = \frac{(2.68 - 6.51)^2}{6.51} + \ldots + \frac{(13.96 - 7.14)^2}{7.14} = 16.39^{**}$$

* denotes significant at 10 per cent level.
** denotes significant at 5 per cent and 10 per cent levels.

Ship age

Using the aggregate percentage shares shown in the last row of Tables 3.8, 3.9, 3.10, 3.11, 3.12 and 3.13 and once again assuming that expected aggregate ship numbers' proportions are given by the world bulk shipping fleet, the following Chi-square statistics, on 4 degrees of freedom, were calculated for the ship numbers' distributions.

Total port calls fleet $$X^2_4 = \frac{(45.64 - 31.54)^2}{31.54} + \ldots + \frac{(2.03 - 6.15)^2}{6.15} = 18.70^{**}$$

Visitors fleet $$X^2_4 = \frac{(49.04 - 31.54)^2}{31.54} + \ldots + \frac{(1.71 - 6.15)^2}{6.15} = 19.54^{**}$$

The Chi-square values for the tonnage distributions were calculated as follows:

Total port calls fleet $$X^2_4 = \frac{(52.52 - 35.89)^2}{35.89} + \ldots + \frac{(1.27 - 3.71)^2}{3.71} = 14.90^{**}$$

Visitors fleet $$X^2_4 = \frac{(51.69 - 35.89)^2}{35.89} + \ldots + \frac{(1.06 - 3.71)^2}{3.71} = 13.88^{**}$$

** denotes significant at 5 per cent and 10 per cent levels.

Ship flag

Employing the aggregate percentage shares shown in the last column of Tables 3.2, 3.3, 3.4, 3.5, 3.6 and 3.7, and once again assuming that expected aggregate ship numbers' proportions are given by the world bulk shipping fleet, the following Chi-square values, on 6 degrees of freedom, were calculated for the ship numbers' distributions.

Total port calls fleet $$X^2_6 = \frac{(47.02 - 29.39)^2}{29.39} + \ldots + \frac{(0.22 - 2.27)^2}{2.27} = 32.19^{**}$$

Visitors fleet $$X^2_6 = \frac{(33.61 - 29.39)^2}{29.39} + \ldots + \frac{(0.48 - 2.27)^2}{2.27} = 14.16^{**}$$

The Chi-square values for the tonnage distributions were calculated as follows:

Total port calls fleet $\quad X^2_6 = \frac{(55.92 - 33.77)^2}{33.77} + \ldots + \frac{(0.16 - 1.95)^2}{1.95} = 35.72^{**}$

Visitors fleet $\quad X^2_6 = \frac{(42.49 - 33.77)^2}{33.77} + \ldots + \frac{(0.29 - 1.95)^2}{1.95} = 17.18^{**}$

** denotes significant at 5 per cent and 10 per cent levels.

APPENDIX IV

DISCRIMINANT ANALYSIS

If the world bulk shipping fleet existing at mid 1986 is divided into the 1985-86 visitors and non-visitors fleets, and if the data describing each vessel in these two fleets is filtered so that only those vessels with details of deadweight tonnage, flag and year of construction are retained, then the remaining bulk ships are distributed as follows:

Visitors fleet	1 464 vessels	(30.3 per cent)
Non-visitors fleet	3 371 vessels	(69.7 per cent)

Discriminant analysis was applied to these two fleet groups, using the following discriminating variables:

- DWT vessel deadweight tonnage (tonnes)
- AGE vessel age (years)
- OECD OECD ship dummy (0,1)
- FOC open registries' ship dummy (0,1)
- CME centrally managed economies' ship dummy (0,1)
- MEOEX Middle East oil exporters' ship dummy (0,1)
- NINDC newly industrialising countries' ship dummy (0,1)
- LDC less developed countries' ship dummy (0,1).

The estimated unstandardised canonical discriminant function took the form:

$$D = -0.5870 + 0.0000164\ DWT - 0.0955\ AGE + 1.0325\ OECD + 0.5944\ FOC$$
$$+ 0.6443\ CME + 1.9571\ MEOEX + 1.9449\ NINDC + 0.1052\ LDC$$

The corresponding standardised canonical discriminant function took the form (in which all the former variables have been standardised):

$$D_z = 0.5058\ DWT_z - 0.6130\ AGE_z + 0.4693\ OECD_z + 0.2798\ FOC_z$$
$$+ 0.2206\ CME_z + 0.2165\ MEOEX_z + 0.6385\ NINDC_z + 0.0271\ LDC_z$$

Diagnostic test results of the analysis were as follows:

- Wilks' Lambda = 0.8395
- Rao's V = 924.1.

The canonical discriminant functions evaluated at the means of each of the eight discriminating variables within the two fleet groups were:

Visitors fleet	$D = D_z = 0.663$
Non-visitors fleet	$D = D_z = -0.288$

The classification results of the analysis are summarised in Table IV.1.

TABLE IV.1 DISCRIMINANT ANALYSIS CLASSIFICATION RESULTS

		Predicted group membership	
Actual group	*Actual group membership*	*Visitors fleet*	*Non-visitors fleet*
Visitors fleet	1 464	978	486
	(100.0)	(66.8)	(33.2)
Non-visitors fleet	3 371	1 065	2 306
	(100.0)	(31.6)	(68.4)

Note Figures in parentheses are percentages.

Sources Discriminant analysis ADP output. BTCE estimates.

$$\text{Vessels correctly classified} = \frac{978 + 2306}{4835} \times 100$$
$$= 67.9 \text{ per cent.}$$

To summarise the results in non-technical terms, the application of discriminant analysis to the visitors and non-visitors fleets showed that the eight variables were placed in the following descending order of relative discriminating power (as indicated by the relative absolute sizes of the coefficients in the estimated standardised discriminant function):

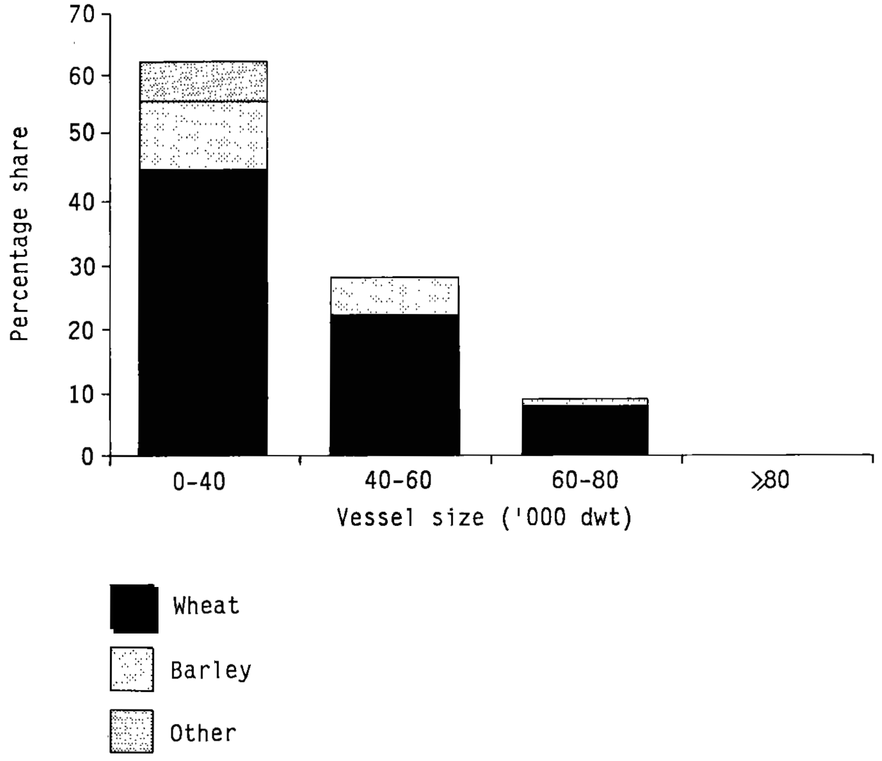
- newly industrialising countries' ships
- age
- deadweight tonnage
- OECD ships
- open registries' ships
- centrally managed economies' ships
- Middle East oil exporters' ships
- less developed countries' ships.

These results are consistent with the tabular, graphical and Chi-square test results (as far as they can be compared) set out in Chapter 3 and its associated Appendixes. They reinforce the conclusions drawn previously that the most likely dry bulk ships to visit Australian ports during 1985-86 bore flags of newly-industrialising or OECD countries, and were recently constructed, large vessels. This conclusion is consistent with the international trading patterns and lengths of trade routes experienced by Australia during 1985-86. It must be remembered, however, that these results apply to Australian trade generally. The results for individually traded commodities might be quite different, and this question is examined in the analysis of grain exports in Chapter 3.

Two reasons why only 68 per cent of bulk ships were correctly classified are:

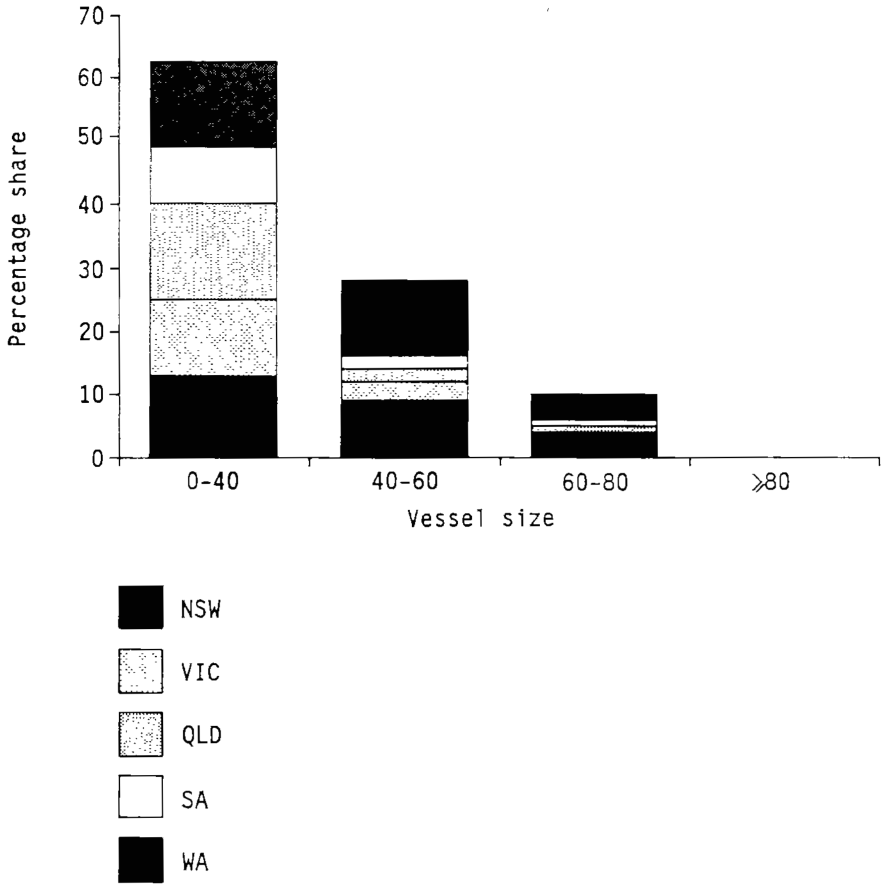
- Australia shares only part of total world trade and therefore some large ships will be engaged in trades other than those involving Australia, for example, Brazilian iron ore exports.
- The predominant use of small ships in the Australian grain trade is unexpected in that smaller ships which actually visit Australia would tend to be classified by the discriminant function as non-visitors.

APPENDIX V GRAIN EXPORT FIGURES



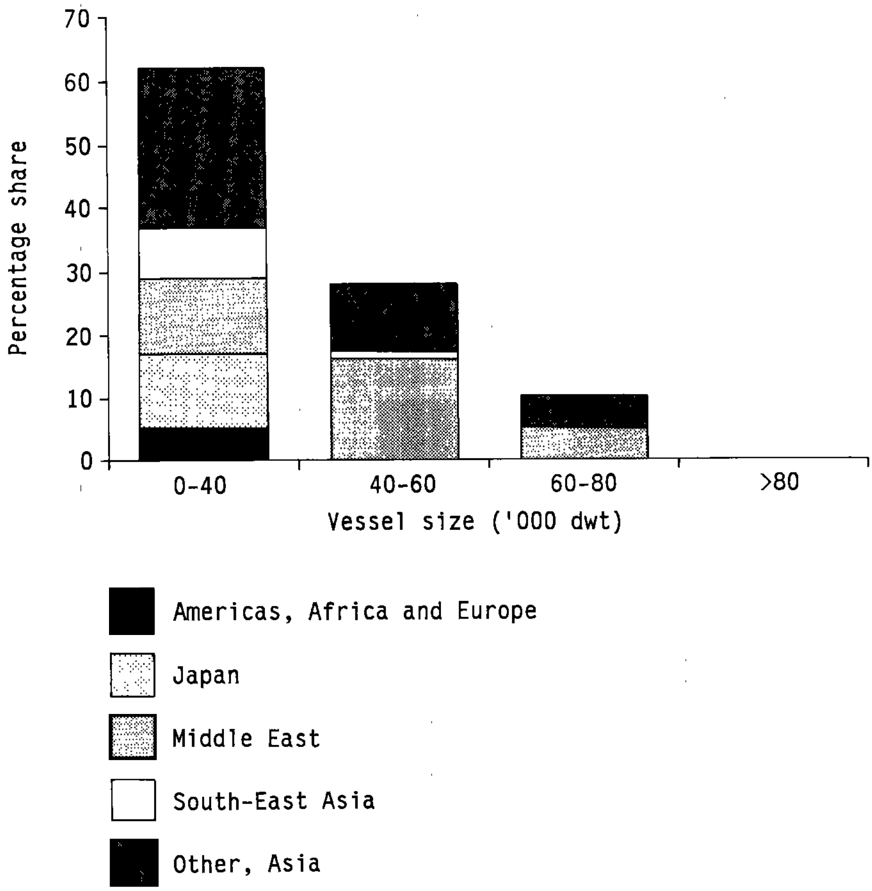
Source BTCE estimates.

Figure V.1 Total Australian grain exports tonnage by grain type by size of bulk carrier, 1985-86



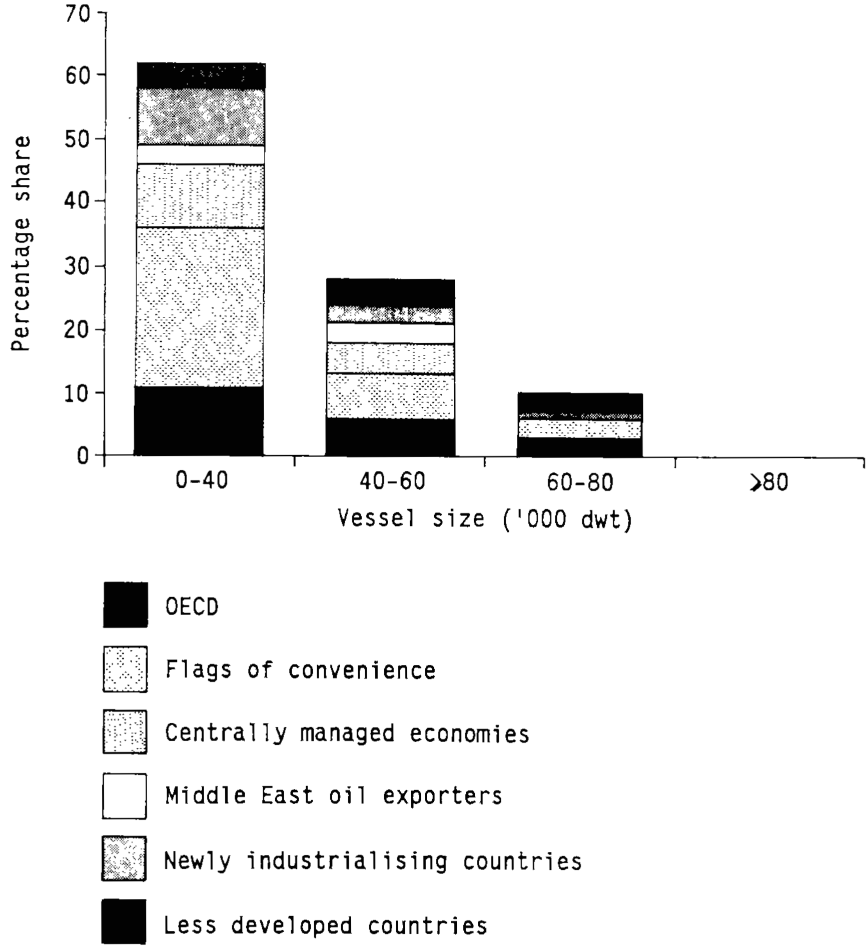
Source BTCE estimates.

Figure V.2 Total Australian grain exports tonnage by State by size of bulk carrier, 1985-86



Source BTCE estimates.

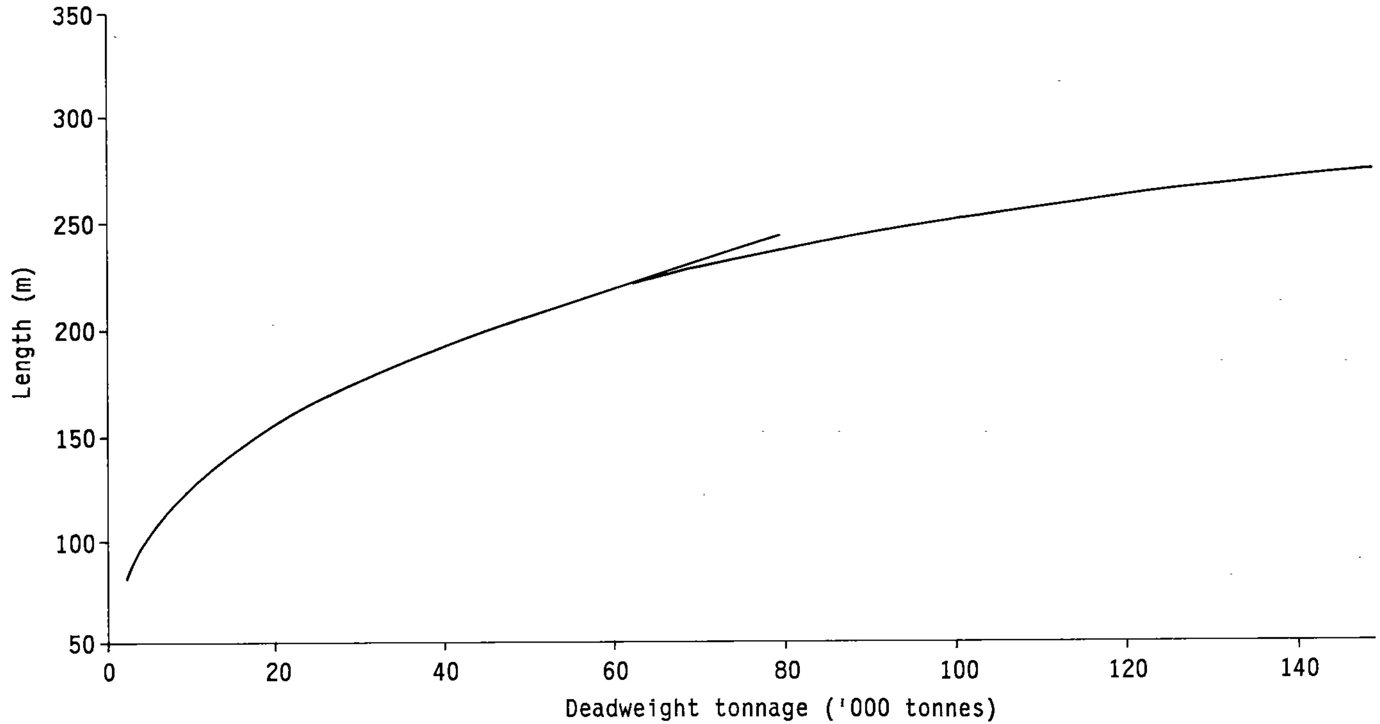
Figure V.3 Total Australian grain exports tonnage by destination by size of bulk carrier, 1985-86



Source BTCE estimates.

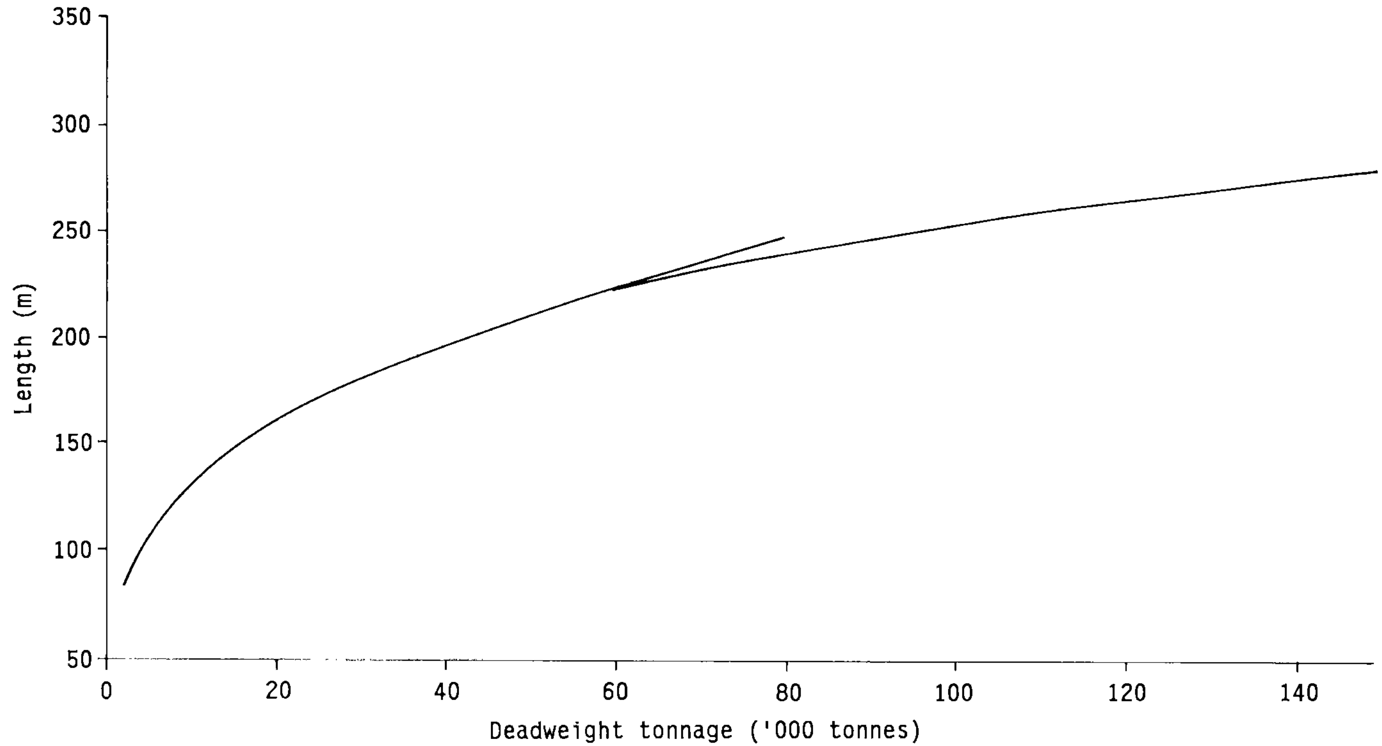
Figure V.4 Total Australian grain exports tonnage by flag by size of bulk carrier, 1985-86

APPENDIX VI SHIP CHARACTERISTICS REGRESSION ANALYSIS FIGURES



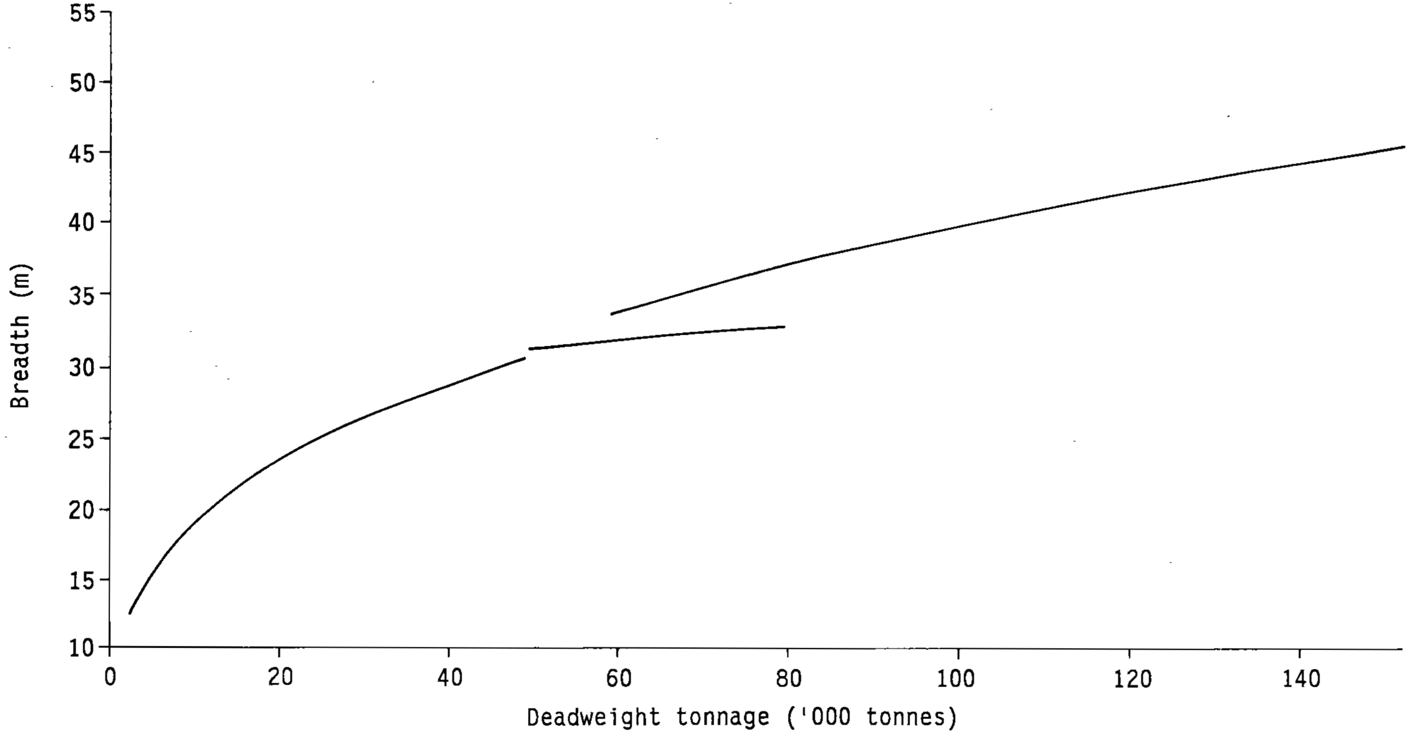
Source BTCE estimates.

Figure VI.1 Length-deadweight tonnage relationship, age = 0



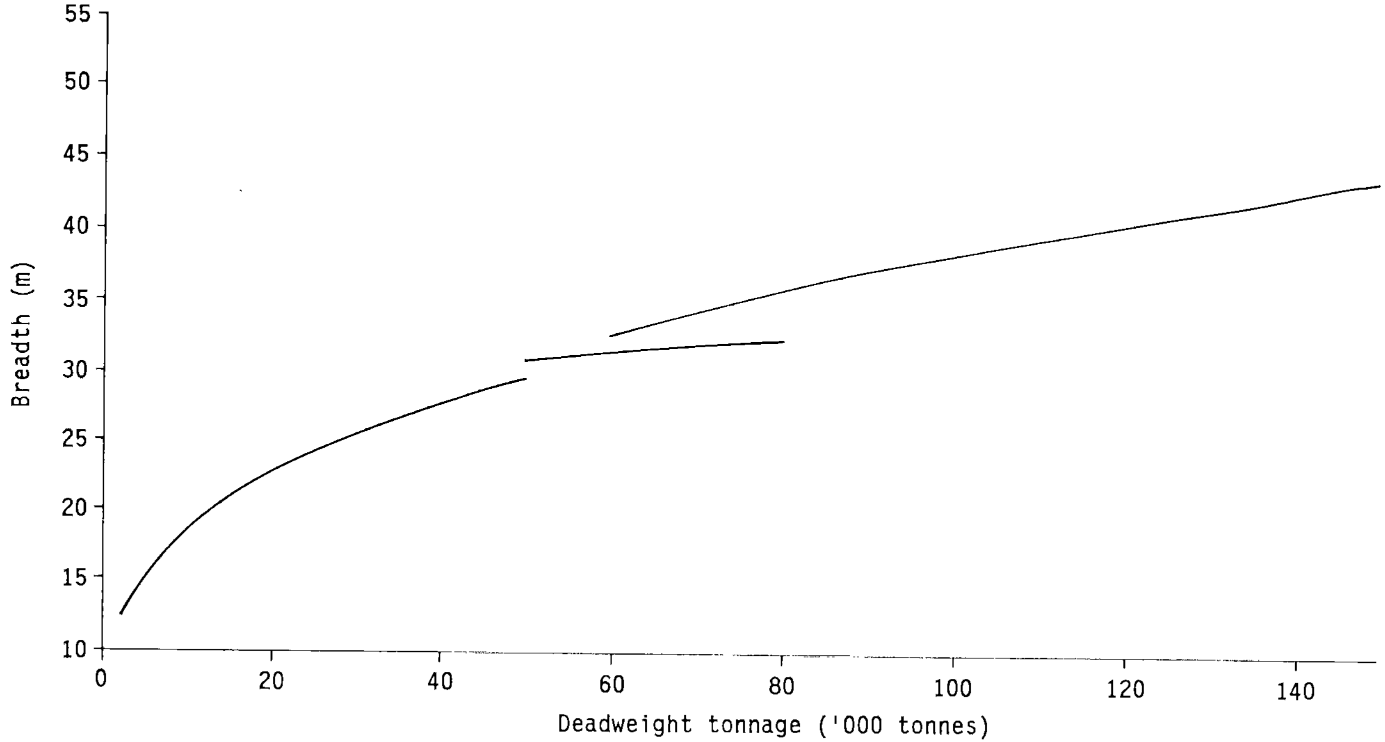
Source BTCE estimates.

Figure VI.2 Length-deadweight tonnage relationship, age = 10



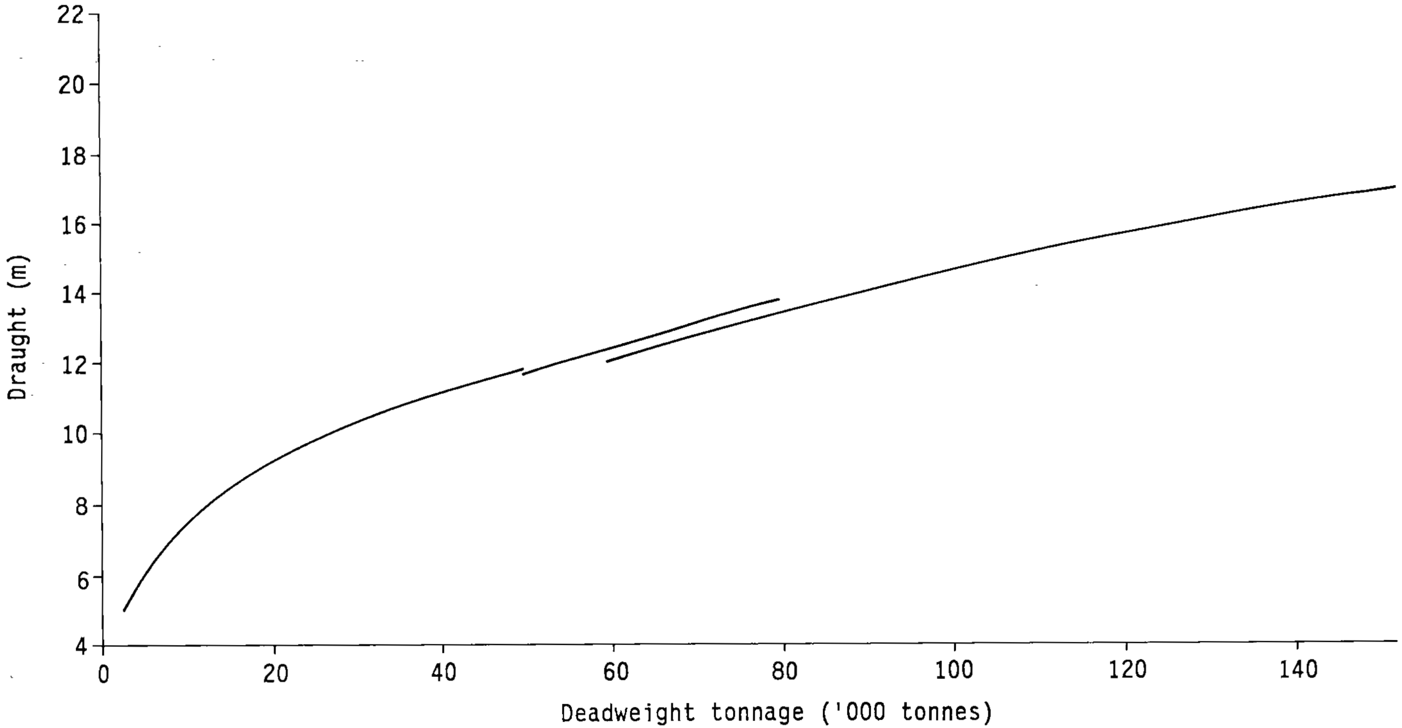
Source BTCE estimates.

Figure VI.3 Breadth-deadweight tonnage relationship, age = 0



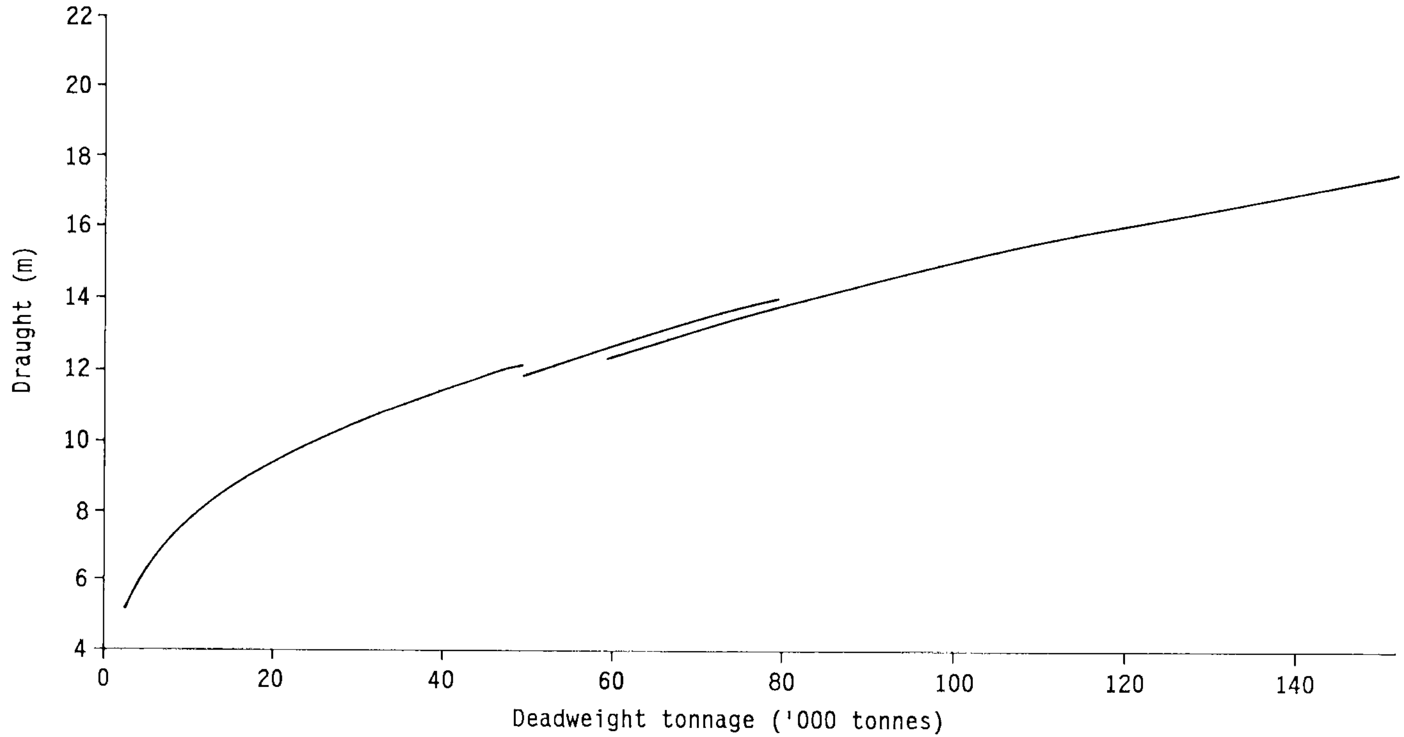
Source BTCE estimates.

Figure VI.4 Breadth-deadweight tonnage relationship, age = 10



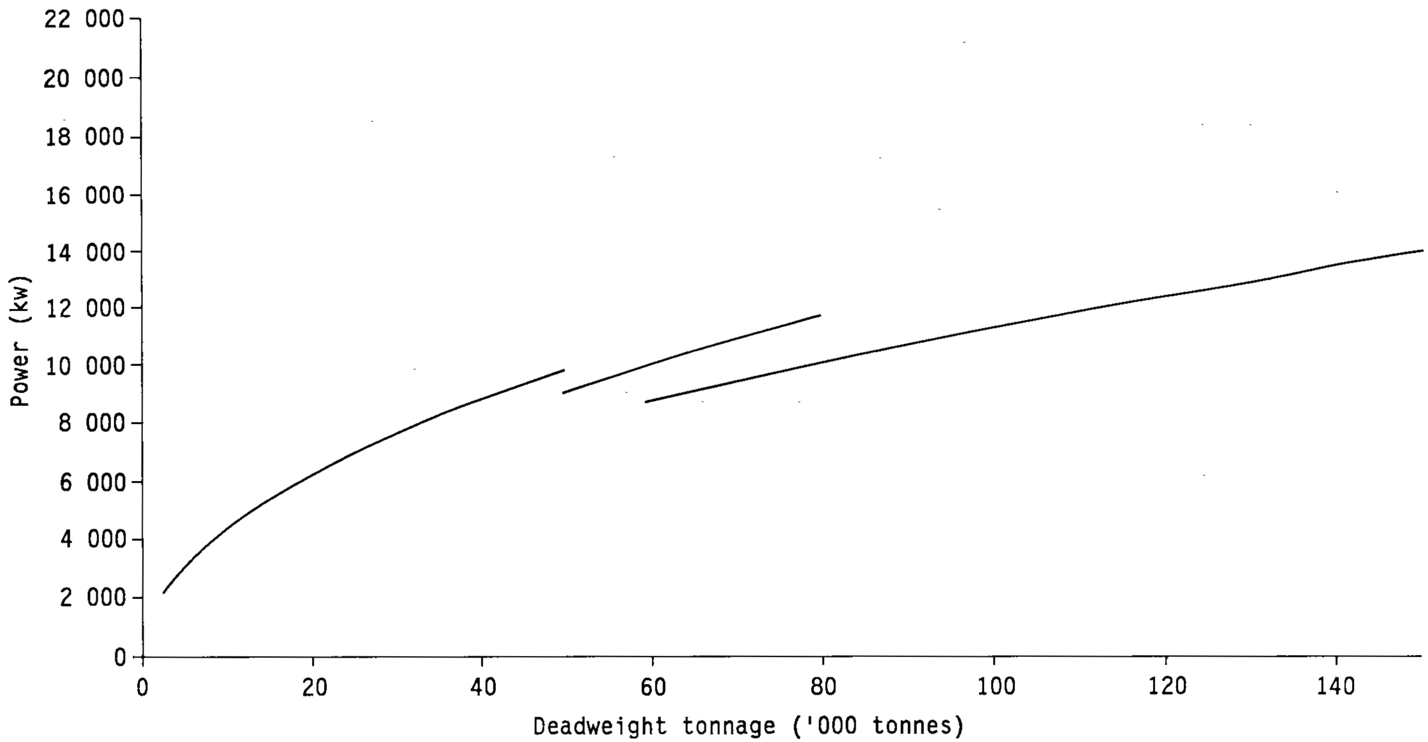
Source BTCE estimates.

Figure VI.5 Draught-deadweight tonnage relationship, age = 0



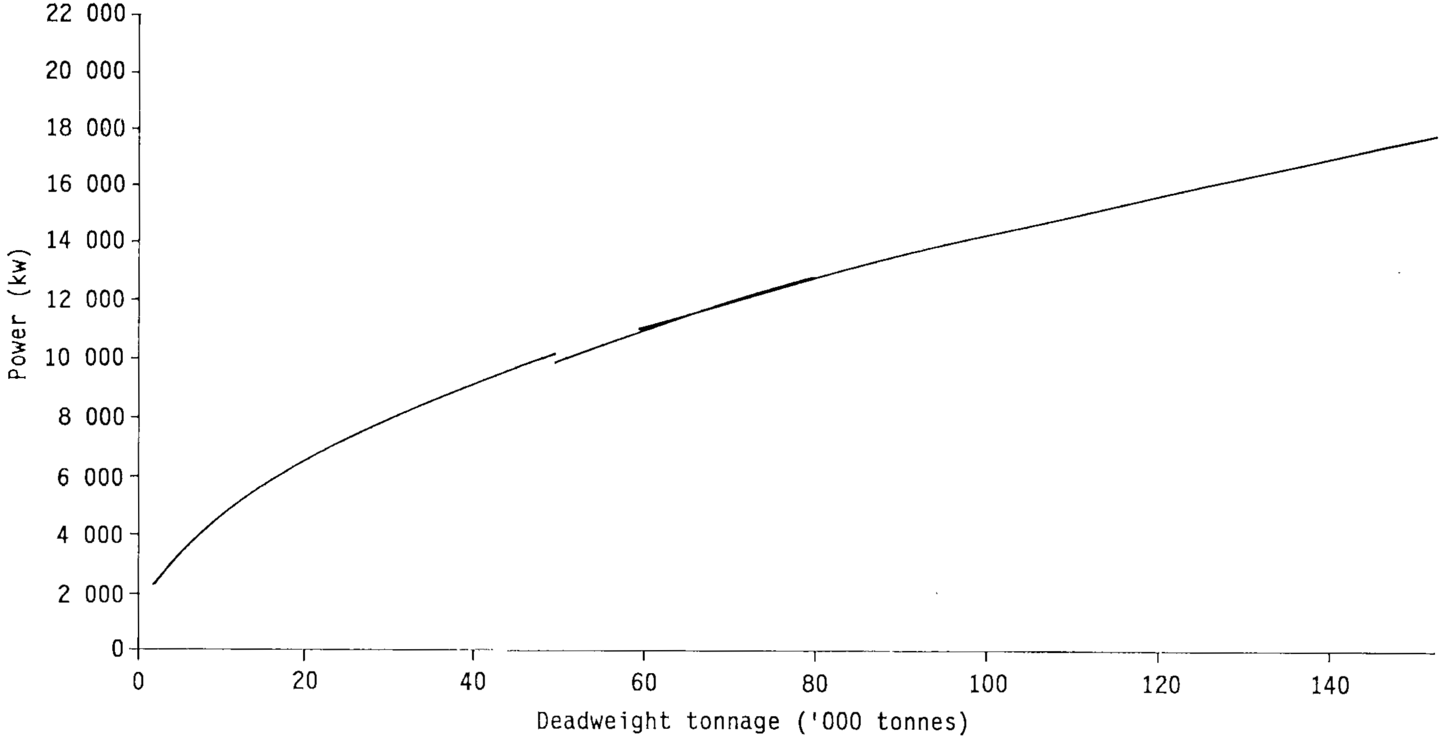
Source BTCE estimates.

Figure VI.6 Draught-deadweight tonnage relationship, age = 10



Source BTCE estimates.

Figure VI.7 Power-deadweight tonnage relationship, age = 0



Source BTCE estimates.

Figure VI.8 Power-deadweight tonnage relationship, age = 10

APPENDIX VII

SHIP CHARACTERISTICS REGRESSION RESIDUAL ANALYSIS

An important issue is the accuracy of the models (estimated in Chapter 5) in predicting ships' characteristics. Apart from the equations for specific fuel consumption based on Lloyds' data, the t-statistics and R^2 values suggest that the equations should be good predictors. However, the theory behind the t-statistics is based on the assumption that the residuals (the difference between predicted and observed values) should follow a normal distribution. A Chi-square test of the residuals indicated the hypothesis that the residuals distributed normally had to be rejected for all of the equations except for the specific fuel cosumption equation based on reported engine performance (Equation 5.1). This indicates that there are some variables omitted from the specifications of the equations. As discussed in Chapter 5, ships are often designed for a specific route. A design that approaches optimum for a specific route can have very different characteristics from the average type of ship predicted by the equations in Table 5.4. However, data were not available to incorporate route variables in the equation.

The rejection of the hypothesis that the residuals are distributed normally also means that the t-statistics must also be treated with caution. However, the size of the sample, which is large by usual regression standards, gives some confidence that the t-statistics are reliable.

A further test of the residuals was made by examining those that exceeded 10 per cent of the observed value for the important dimensions of length, breadth and draught and 20 per cent for power. The proportion of the sample for which the residuals exceeded these percentages were:

- length - 4 per cent
- breadth - 5 per cent
- draught - 2 per cent
- power - 18 per cent.

These figures imply that the equations are reliable for length, breadth and draught. Generally, where the equations gave results which differed from the observed values by more than the above percentages, they tended to underestimate the length and overestimate breadth and power. Errors in the estimation of draught were less pronounced but had a small tendency to overestimation.

APPENDIX VIII

MEASURES SUPPORTING THE LOWER THRESHOLD OF MODERNISATION

Navigation is supported with the following devices and facilities:

- collision avoidance system
- positioning fixing device
- automatic navigation
- automatic steering
- navigation route estimation
- UHF ship's interior communication system
- satellite communication system
- weather facsimile
- wheelhouse arrangement.

Mooring and cargo handling system:

- hydraulic operated anchoring
- automatic tensioning winch system
- remote operated mooring
- hydraulic mooring winches
- easy tug-line handling devices
- central remote control of cargo handling
- central remote control of ballast handling
- loading calculator
- one-man control system.

Hotel service and safety control:

- accommodation arrangement (single berth cabin and only one large public room for total complement)

- lift between engine room and bridge
- rationalised arrangement for cooking and catering services
- self service system for cabin maintenance.

Ship's safety:

- central fire detecting system
- easy handling and maintenance of fire extinguishing devices.

Engine room:

- unmanned engine room
- centralised monitoring
- increased reliability for machinery
- automated standby conditions
- card system for spare parts and tools
- data logger for recording.

Machinery:

- automatic operation and remote control of most generators, pumps.

Miscellaneous:

- change-over device of fuel from heavy oil to diesel oil
- automatic temperature setting for tanks
- automatic oil strainer for oil cleaning
- automatic control of cool water temperature
- preferential trip of electrical equipment at overload on electric generator
- engine telegraph with telegraph logger.

APPENDIX IX

JAPANESE SEAMEN'S ALLOWANCES AND BONUSES

Allowances and bonuses allocated to crew members:

- functional additions for master and chief engineer, chief radio officer, first mate and first engineer
- family allowances
- master and chief engineer allowances
- engine department allowance
- 'M-zero' engine room allowance
- holiday overtime allowance
- hourly overtime
- daily navigation allowance
- vacancy allowance
- overtime premiums
- night shift allowances for bridge watchkeeping duties
- yearly (summer and year end) bonuses
- head of ratings' deck or engine or catering department
- yearly recreation on-shore leave (37 days)
- functional addition for purser
- health supervision allowance.

Allowances and bonuses estimated by taking 10 per cent of total basic wages:

- provisional upgrading allowance
- prolonged voyage allowance
- prohibitive work allowance for following activities
  - loading and/or unloading of dry cargoes

  - loading and/or unloading mail and valuables
  - tallying dry cargoes
  - hoist operation in loading and/or unloading
  - cargo shifting in a hold
  - scaling the interior of a boiler
  - replacement of water tubes and breechings
  - installing and demounting cargo hoses on tankers
  - loading 100 kg or more of ship's provisions per port overseas
  - cleaning the bark away
- work allowances for work such as
  - cleaning a hold
  - hatch work
  - extra work in engine department
  - sanitary work
- dangerous cargo bonus for explosives, inflammables or corrosives
- master's pilotage bonus
- coal/iron-dust ignition bonus
- night work bonus for other than watchkeeping duties.

At least 10 per cent of basic earnings has been allocated to wages off articles that are paid in the form of on-shore allowances, standby allowances, supplementary allowances to seafarers who are awaiting employment, attending schools and courses, outfitting vessels, classified as a seafarer stationed ashore, temporarily suspended and so on.

Ten per cent of savings on crew numbers (from 25-18) was assumed to constitute additional rewards for dual purpose crew who perform dual (engine and deck) functions, thus enabling the reduction to 18.

APPENDIX X ANNUAL CAPITAL CHARGES TABLES

TABLE X.1 ANNUAL CAPITAL CHARGE FOR A NEW 65 000 DWT BULK CARRIER - 10 PER CENT RETURN ON EQUITY[a]
(US$ '000)

Period half year	Principal repayment	Loan balance	Interest on loan	Cumulative[b] depreciation	Net equity	Return[c] on equity	Total[d] outflow	Discount[f] factor	Net present value
1	0	0	0	0	3 748	0	3 748	1.276	4 782
2	0	3 748	0	0	3 748	187	187	1.216	227
3	0	7 496	150	0	3 748	187	337	1.158	390
4	0	11 244	300	0	3 748	187	487	1.102	537
5	0	14 992	450	0	3 748	187	637	1.050	669
6	882	14 110	600	625	4 005	187	1 669	0.952	1 589
7	882	13 228	564	1 250	4 262	200	1 646	0.907	1 493
8	882	12 346	529	1 875	4 519	213	1 624	0.864	1 403
9	882	11 464	494	2 500	4 776	226	1 602	0.823	1 318
10	882	10 582	459	3 125	5 033	239	1 580	0.784	1 239
11	882	9 700	423	3 750	5 290	252	1 557	0.746	1 162
12	882	8 818	388	4 375	5 547	265	1 535	0.711	1 091
13	882	7 936	353	5 000	5 804	277	1 512	0.677	1 024
14	882	7 054	317	5 625	6 061	290	1 489	0.645	960
15	882	6 172	282	6 250	6 318	303	1 467	0.614	901
16	882	5 290	247	6 875	6 575	316	1 445	0.585	845
17	882	4 408	212	7 500	6 832	329	1 423	0.557	793
18	882	3 526	176	8 125	7 089	342	1 400	0.530	742
19	882	2 644	141	8 750	7 346	354	1 377	0.505	695
20	882	1 762	106	9 375	7 603	367	1 355	0.481	652
21	882	880	70	10 000	7 860	380	1 332	0.458	610
22	880	0	35	10 625	8 117	393	1 308	0.436	570
23	0	0	0	11 250	7 492	406	406	0.416	169

TABLE X.1 (Cont.) ANNUAL CAPITAL CHARGE FOR A NEW 65 000 DWT BULK CARRIER - 10 PER CENT RETURN ON EQUITY[a]

(US$ '000)

Period half year	*Principal repayment*	*Loan balance*	*Interest on loan*	*Cumulative[b] depreciation*	*Net equity*	*Return[c] on equity*	*Total[d] outflow*	*Discount[f] factor*	*Net present value*
24	0	0	0	11 875	6 867	375	375	0.396	149
25	0	0	0	12 500	6 242	343	343	0.377	129
26	0	0	0	13 125	5 617	312	312	0.359	112
27	0	0	0	13 750	4 992	281	281	0.342	96
28	0	0	0	14 375	4 367	250	250	0.326	82
29	0	0	0	15 000	3 742	218	218	0.310	68
30	0	0	0	15 625	3 117	187	187	0.295	55
31	0	0	0	16 250	2 492	156	156	0.281	44
32	0	0	0	16 875	1 867	125	125	0.268	34
33	0	0	0	17 500	1 242	93	93	0.255	24
34	0	0	0	18 125	617	62	62	0.243	15
35	0	0	0	18 740	0	31	31	0.231	7
									24 676

a. OECD conditions are used, that is, loan period = 8.5 years; interest on loan = 8.0 per cent per annum; 20 per cent deposit paid by shipowner.
b. Straight line depreciation over the 15-year economic life of the ship.
c. 10 per cent return on equity.
d. Total outflow = principal repayment + interest on loan + return on equity.
f. Discount rate of 10 per cent per annum.

Note Ship price = $18.74m; annuity = $3.244m per annum; capital recovery ratio = 17 per cent; economic life of the vessel = 15 years; residual value after 15 years = 0.

Source BTCE estimates.

TABLE X.2 ANNUAL CAPITAL CHARGE FOR A 5-YEAR OLD 65 000 DWT BULK CARRIER - 10 PER CENT RETURN ON EQUITY[a]

(US$ '000)

Period half year	*Principal repayment*	*Loan balance*	*Interest on loan*	*Cumulative[b] depreciation*	*Net equity*	*Return[c] on equity*	*Total[d] outflow*	*Discount[f] factor*	*Net present value*
1	0	3 898	0	0	3 898	0	3 898	0.952	3 711
2	390	3 507	273	390	3 898	195	858	0.864	741
3	390	3 118	246	780	3 898	195	831	0.823	684
4	390	2 728	218	1 170	3 898	195	803	0.784	630
5	390	2 338	191	1 560	3 898	195	776	0.746	579
6	390	1 948	164	1 950	3 898	195	749	0.711	533
7	390	1 558	136	2 340	3 898	195	721	0.677	488
8	390	1 168	109	2 730	3 898	195	694	0.645	448
9	390	778	82	3 120	3 898	195	667	0.614	410
10	390	388	55	3 510	3 898	195	639	0.585	374
11	388	0	27	3 900	3 898	195	612	0.557	341
12	0	0	0	4 290	3 510	195	195	0.530	103
13	0	0	0	4 680	3 120	175	175	0.505	88
14	0	0	0	5 070	2 730	156	156	0.481	75
15	0	0	0	5 460	2 340	136	136	0.458	62
16	0	0	0	5 850	1 950	117	117	0.436	51

TABLE X.2 (Cont.) ANNUAL CAPITAL CHARGE FOR A 5-YEAR OLD 65 000 DWT BULK CARRIER - 10 PER CENT RETURN ON EQUITY[a]

(US$ '000)

Period half year	*Principal repayment*	*Loan balance*	*Interest on loan*	*Cumulative[b] depreciation*	*Net equity*	*Return[c] on equity*	*Total[d] outflow*	*Discount[f] factor*	*Net present value*
17	0	0	0	6 240	1 560	97	97	0.416	40
18	0	0	0	6 630	1 170	78	78	0.396	31
19	0	0	0	7 020	780	58	58	0.377	22
20	0	0	0	7 410	390	39	39	0.359	14
21	0	0	0	7 795	0	19	19	0.342	6
									9 431

a. Loan amount = 50 per cent of purchase price; interest on loan = 14 per cent per annum; loan period = 5 years.
b. Straight line depreciation over the 10-year remaining life of the ship.
c. 10 per cent return on equity.
d. Total outflow = principal repayment + interest on loan + return on equity.
f. Discount rate of 10 per cent per annum.

Note Ship price = $7.8m; annuity = $1.535m per annum; capital recovery ratio = 20 per cent; remaining economic life of the vessel = 10 years; residual value after 15 years ≅ 0.

Source BTCE estimates.

TABLE X.3 ANNUAL CAPITAL CHARGE FOR A NEW 65 000 DWT BULK CARRIER - ZERO RETURN ON EQUITY[a]

(US$ '000)

Period half year	*Principal repayment*	*Loan balance*	*Interest on loan*	*Cumulative[b] depreciation*	*Net equity*	*Return[c] on equity*	*Total[d] outflow*	*Discount[f] factor*	*Net present value*
1	0	0	0	0	3 748	0	3 748	1.276	4 782
2	0	3 748	0	0	3 748	0	0	1.216	0
3	0	7 496	150	0	3 748	0	150	1.158	174
4	0	11 244	300	0	3 748	0	300	1.102	330
5	0	14 992	450	0	3 748	0	450	1.050	473
6	882	14 110	600	625	4 005	0	1 482	0.952	1 411
7	882	13 228	564	1 250	4 262	0	1 446	0.907	1 312
8	882	12 346	529	1 875	4 519	0	1 411	0.864	1 219
9	882	11 464	494	2 500	4 776	0	1 376	0.823	1 132
10	882	10 582	459	3 125	5 033	0	1 341	0.784	1 051
11	882	9 700	423	3 750	5 290	0	1 305	0.746	974
12	882	8 818	388	4 375	5 547	0	1 270	0.711	903
13	882	7 936	353	5 000	5 804	0	1 235	0.677	836
14	882	7 054	317	5 625	6 061	0	1 199	0.645	773
15	882	6 172	282	6 250	6 318	0	1 164	0.614	715
16	882	5 290	247	6 875	6 575	0	1 129	0.585	660
17	882	4 408	212	7 500	6 832	0	1 094	0.557	609
18	882	3 526	176	8 125	7 089	0	1 058	0.530	561
19	882	2 644	141	8 750	7 346	0	1 023	0.505	517
20	882	1 762	106	9 375	7 603	0	988	0.481	475
21	882	880	70	10 000	7 860	0	952	0.458	436
22	880	0	35	10 625	8 117	0	915	0.436	399
23	0	0	0	11 250	7 492	0	0	0.416	0

TABLE X.3 (Cont.) ANNUAL CAPITAL CHARGE FOR A NEW 65 000 DWT BULK CARRIER - ZERO RETURN ON EQUITY[a]

(US$ '000)

Period half year	*Principal repayment*	*Loan balance*	*Interest on loan*	*Cumulative[b] depreciation*	*Net equity*	*Return[c] on equity*	*Total[d] outflow*	*Discount[f] factor*	*Net present value*
24	0	0	0	11 875	6 867	0	0	0.396	0
25	0	0	0	12 500	6 242	0	0	0.377	0
26	0	0	0	13 125	5 617	0	0	0.359	0
27	0	0	0	13 750	4 992	0	0	0.342	0
28	0	0	0	14 375	4 367	0	0	0.326	0
29	0	0	0	15 000	3 742	0	0	0.310	0
30	0	0	0	15 625	3 117	0	0	0.295	0
31	0	0	0	16 250	2 492	0	0	0.281	0
32	0	0	0	16 875	1 867	0	0	0.268	0
33	0	0	0	17 500	1 242	0	0	0.255	0
34	0	0	0	18 125	617	0	0	0.243	0
35	0	0	0	18 740	0	0	0	0.231	0
									19 742

a. OECD conditions are assumed, that is, loan period = 8.5 years; interest on loan = 8 per cent per annum; 20 per cent deposit paid by shipowner.
b. Straight line depreciation over the 15-year economic life of the ship was assumed.
c. Zero return on equity.
d. Total outflow = principal repayment + interest on loan + return on equity.
f. Discount rate of 10 per cent per annum.

Note Ship price = $18.74m; annuity = $2.596m per annum; capital recovery ratio = 14 per cent; economic life of the vessel = 15 years; residual value after 15 years = 0.

Source BTCE estimates.

TABLE X.4 ANNUAL CAPITAL CHARGE FOR A 5-YEAR OLD 65 000 DWT BULK CARRIER - ZERO RETURN ON EQUITY[a]

(US$ '000)

Period half year	*Principal repayment*	*Loan balance*	*Interest on loan*	*Cumulative[b] depreciation*	*Net equity*	*Return[c] on equity*	*Total[d] outflow*	*Discount[f] factor*	*Net present value*
1	0	3 898	0	0	3 898	0	3 898	0.952	3 711
2	390	3 508	273	390	3 898	0	663	0.864	573
3	390	3 118	246	780	3 898	0	636	0.823	523
4	390	2 728	218	1 170	3 898	0	608	0.784	477
5	390	2 338	191	1 560	3 898	0	581	0.746	433
6	390	1 948	164	1 950	3 898	0	554	0.711	394
7	390	1 558	136	2 340	3 898	0	526	0.677	356
8	390	1 168	109	2 730	3 898	0	499	0.645	322
9	390	778	82	3 120	3 898	0	472	0.614	290
10	390	388	55	3 510	3 898	0	445	0.585	260
11	388	0	27	3 900	3 898	0	415	0.557	231
12	0	0	0	4 290	3 510	0	0	0.530	0
13	0	0	0	4 680	3 120	0	0	0.505	0
14	0	0	0	5 070	2 730	0	0	0.481	0
15	0	0	0	5 460	2 340	0	0	0.458	0
16	0	0	0	5 850	1 950	0	0	0.436	0

TABLE X.4 (Cont.) ANNUAL CAPITAL CHARGE FOR A 5-YEAR OLD 65 000 DWT BULK CARRIER - ZERO RETURN ON EQUITY[a]
(US$ '000)

Period half year	*Principal repayment*	*Loan balance*	*Interest on loan*	*Cumulative[b] depreciation*	*Net equity*	*Return[c] on equity*	*Total[d] outflow*	*Discount[f] factor*	*Net present value*
17	0	0	0	6 240	1 560	0	0	0.416	0
18	0	0	0	6 630	1 170	0	0	0.396	0
19	0	0	0	7 020	780	0	0	0.377	0
20	0	0	0	7 410	390	0	0	0.359	0
21	0	0	0	7 795	0	0	0	0.342	0
									7 570

a. Loan amount = 50 per cent of purchase price; interest on loan = 14 per cent per annum; loan period ≈ 5 years.
b. Straight line depreciation over the 10-year remaining life of the ship.
c. Zero return on equity.
d. Total outflow = principal repayment + interest on loan + return on equity.
f. Discount rate of 10 per cent per annum.

Note Ship price = $7.8m; annuity = $1.232m per annum; capital recovery ratio ≈ 16 per cent; remaining economic life of the vessel = 10 years; residual value after 15 years ≈ 0.

Source BTCE estimates.

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ABBREVIATIONS

AB	Able seaman
ABS	Australian Bureau of Statistics
ARPA	Advanced Radar Plotting Aid
AUS	Australian flag
BHP	Broken Hill Proprietary Co. Ltd
BTCE	Bureau of Transport and Communications Economics
C&F	Cost and Freight
CIF	Cost, Insurance, Freight
CME	Centrally Managed Economy
CSL	Canadian Steamship Line
DPC	Dual Purpose Crew
DPO	Dual Purpose Officer
DTC	Department of Transport and Communications
DW	Durbin-Watson Statistic
dwt	deadweight tonnes
EEC	European Economic Community
ESP	Efficient Ship Programme
FGMDSS	Future Global Maritime Distress and Safety System
FIO	Free In and Out
FOB	Free-on-board
FOC	Flag of Convenience
FRG	Federal Republic of Germany
g/kw-h	grams per kilowatt-hour
GDR	German Democratic Republic
GPC	General Purpose Crew
GPO	General Purpose Officer
GPS	Global Positioning System
H&M	Hull and Machinery
HEFA	High Efficiency Flow Adapted
HVO	Heavy Viscosity Oil
ILO	International Labour Office
IoM	Isle of Man
ISF	International Shipping Federation

ISL	Institute of Shipping Economics and Logistics
ITF	International Transport Workers' Federation
kw	kilowatt
LDC	Less Developed Country
MCR	Maximum Continuous Rating
MEOEX	Middle East Oil Exporter
MIDC	Maritime Industry Development Committee
NINDC	Newly Industrialising Country
NIS	Norwegian International Shipping Registry
NYK	Nippon Yusen Kaisha
obo	ore-bulk-oil carrier
OECD	Organisation for Economic Co-operation and Development
P and I	Protection and Indemnity
R&M	Repairs and Maintenance
rpm	revolutions per minute
SACCS	Shipping and Air Cargo Commodity Statistics
SdZ	Schiff der Zukunft (that is, *Ship of the Future*)
SFC	Specific Fuel Consumption
SIO	Semi-integrated Officer
t/d	tonnes per day
TNT	Thomas Nationwide Transport Limited
UK	United Kingdom
USA	United States of America
USSR	Union of Soviet Socialist Republics
WO	Watch Officer