An Estimate of Operating Costs for Bulk, Ro-ro and Container Ships

Information Paper

Estimates of the operating costs of ships are central to the analysis of a range of issues in shipping and ports investment and operations. As part of BTE studies a substantial body of information on ships operations had been assembled. This paper has generalised that information into statistical relationships for three ship types serving Australia - Bulk, Roll on/Roll off and Container Vessels. The scheme for the analysis follows that of Goss (1974).

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FOREWORD

Estimates of the operating costs of ships are central to the analysis of a range of issues in shipping and ports investment and operations. As part of BTE studies a substantial body of information on ships operations had been assembled. This paper has generalised that information into statistical relationships for three ship types serving Australia — Bulk, Roll on/Roll off and Container Vessels. The scheme for the analysis follows that of Goss (1974).

These cost relationships are generally applicable to ships operating in mid 1978 and were adopted for BTE studies which were current immediately following their development. Their publication forms part of the record of information used in BTE studies.

The cost relationships presented here do not represent any specific vessel in any specific trade. Rather they indicate the expected average cost where no other information on specific vessels, operating practices, or trade characteristics is available. The characteristics of specific vessels, company practices and trades will lead to cost structures which will differ from the averages in this paper — although generally lying within the ranges indicated. Over time — and four years have already elapsed — technological, institutional and other industry changes will lead to changes in these cost functions. Some of these changes are discussed in the paper. Others will operate in a pervasive manner and their effects are difficult to estimate within the framework of this paper. Care must therefore be taken in extending these relationships too far in times of change in the shipping industry.

The work in this paper was prepared by Mr N. F. Gentle and Mr R. J. Perkins.

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Bureau of Transport Economics
Canberra, September 1982

CONTENTS

TABLES

FIGURES

CHAPTER 1 - INTRODUCTION

BACKGROUND

This paper originated as a result of several recent studies undertaken by the Bureau where ship operating costs were an important element. A number of generalised cost functions or models were developed as part of those studies. These costs have been drawn together in this information paper so that they may be available to others working in the same general field.

Separate operating cost models are presented for:

- bulk;
- roll on roll off (ro-ro); and
- fully cellular container ships.

Each model is applicable across its own specified deadweight tonnage range, and is made up of the following cost items:

- capital;
- fuel at sea and in port;
- crewing;
- insurance;
- repairs and maintenance; and
- victuals and stores.

Navigation, port and canal charges have not been included with the operating cost estimates because they vary markedly from port to port. A discussion of the types of charges levied and the information needed to calculate these charges is presented in Appendix I.

All cost models in this paper have been developed using 1978 as a base year, however operating costs at 1980 prices have also been presented. The method used to adjust the operating costs has been given in Appendix II.

The origin of all data used in this paper has been documented wherever possible, to assist those wishing to conduct further work.

PURPOSE OF THE PAPER

The purpose of this paper is to:

- develop daily operating costs for bulk, ro-ro and fully cellular container ships over a range of sizes for each ship type;
- set out the underlying assumptions so that costs can be adjusted or selected to suit the analysis needs; and
- provide information and promote discussion.

The cost models have been developed from information supplied by operators and from shipping literature. All costs presented are therefore commercial rather than economic costs, in the sense that they include profits, taxes, subsidies and other allowances inherent in the market. To obtain economic costs, all elements of subsidy, taxes and other distortions would need to be separated from the commercial costs. As this is often difficult to perform, and probably impossible for ship capital cost estimation, a commercial cost approach has been adopted throughout.

FORM OF THE COST MODELS

The cost models presented in this paper are of two forms:

- $A=\alpha \,.\, (B)^{\beta} \,.\, \epsilon$ - power equation
- $A=\alpha+\beta \,.\, (B)+\epsilon$ - linear equation.

In these equations, the A term is referred to as the dependent variable and the B term as the independent variable. The α, and β terms have been estimated in each case by performing a linear regression analysis on the two variables. The ϵ term in the equations is known as the stochastic error. It is included in each equation to describe any unpredictable randomness in the data which might arise from a lack of inclusion of all significant variables that could influence the equation, as well as errors in the measurement or recording of the data. Provided that the relationship between the dependent and independent variables in each equation is a statistically significant one the stochastic error term can be ignored (ie assumed equal to unity in the case of power equations or zero for linear models).

GUIDE TO THE PAPER

This paper separately considers six operating cost items (Chapters 2 to 7) and draws them together in a summary chapter (Chapter 8). Sensitivity tests on the operating costs is presented in Chapter 9. A series of appendices provides background and supporting information on the derivation of the cost items presented in the body of the paper.

CHAPTER 2 - CAPITAL COST OF SHIPS AND THEIR EQUIPMENT

INTRODUCTION

This chapter presents an estimate of the capital cost of bulk, ro-ro and fully cellular container ships. The estimates are based on contract values for new ships ordered during 1977 and 1978 from shipyards located mainly in the UK, Europe and Japan. This information was collected from shipping literature as well as from correspondence with ship builders. The capital cost estimates for the three ship types mentioned in this paper are therefore based on new ship costs for vessels built during 1977 and 1978, and have been standardised to mid 1978. No estimate has been made of the present worth of older ships, although it could be expected that their capital component would be lower than that estimated here for new vessels at 1978.

The ship cost estimates developed in this paper are in commercial rather than economic terms, because contract values for new ships often do not reflect the value of the resources used to construct the vessel. Many ship building yards around the world now receive various forms of support from their governments which can have an effect on the cost that the purchaser pays for the vessel. Further discussion of the market related factors that can affect contract values for vessels is given in Appendix III.

Daily capital cost estimates for each of the three ship types have been derived by discounting the estimated cost of the ship over its expected life. The Australian Government long term bond rate has been chosen as the appropriate discount rate, with a vessel life of 15 years. A zero residual value has been assumed at the end of the vessels life because the vessel would be fully discounted at that time. Because a discounting method has been chosen for allocating the capital cost over the vessels life, no allowance for ship replacement has been included.

SHIP CAPITAL COST ESTIMATE

Capital cost estimates for bulk, ro-ro and fully cellular container ships are presented in Table 2.1 in mid 1978 dollars. A graphical presentation of these estimates for each ship type, including 90 per cent confidence limits about the mean value[1], is shown in Figures 2.1 to 2.3.

TABLE 2.1—SHIP CAPITAL COST ESTIMATE: REGRESSION COEFFICIENTS AND STATISTICS FOR MODEL,[a]
$C=\alpha \cdot (DWT)^{\beta} \cdot \epsilon$

Ship type	α	β	Sample Size	R^2
Bulk	1.5083	0.6028	44	0.67
	(1.83)	(9.23)		
Ro-ro	3.1388	0.6942	35	0.73
	(7.38)	(9.56)		
Container	1.4471	0.8528	38	0.74
	(1.62)	(10.02)		

a. Capital cost estimate C is in $A millions at June 1978, DWT refers to thousands of deadweight tonnes. t statistic is shown in brackets below coefficient estimate. ϵ is the stochastic error term and is assumed to equal one.

Source: Based on ship prices reported in Fairplay International Shipping Weekly, Drewry Statistics and Economics and Japanese shipbuilding sources for the period January 1977 to October 1978.

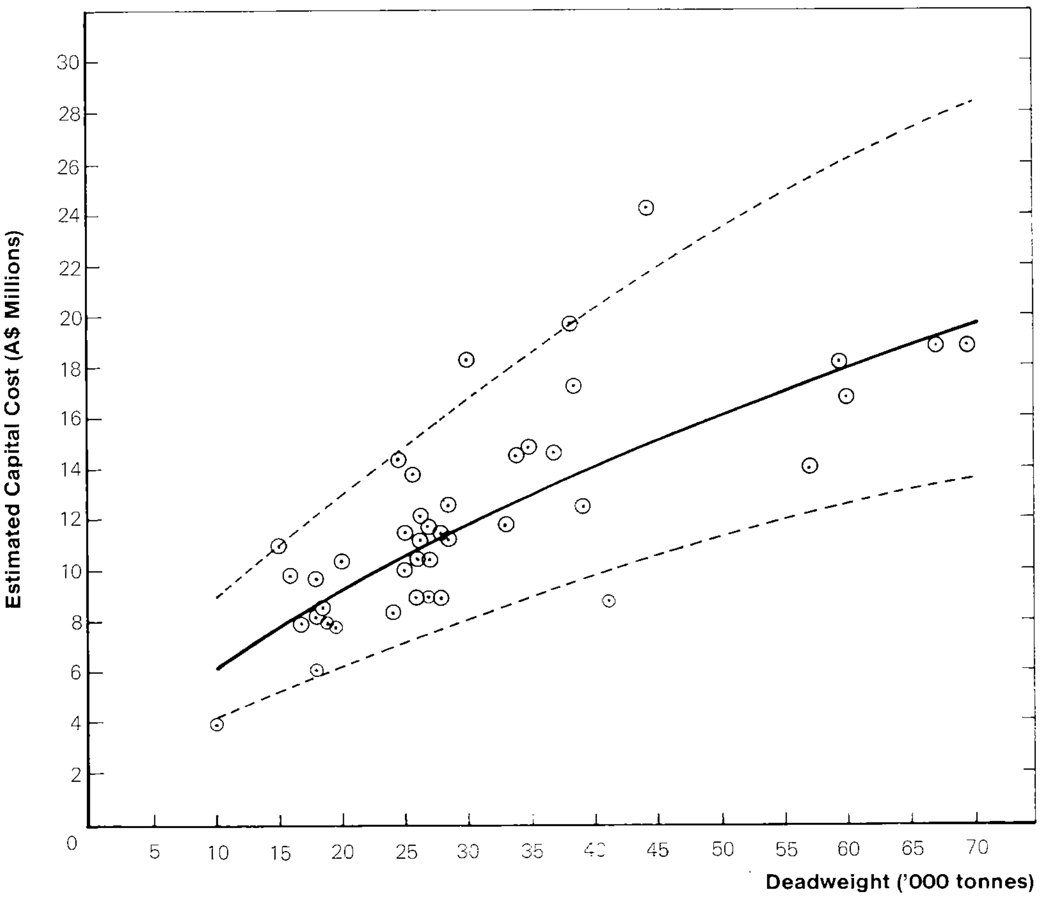
The capital cost estimates in Table 2.1 are applicable to a range of ship sizes. For each ship type this range was determined by the spread of ship sizes for which contract values were available during 1977 and 1978. The deadweight tonnage (DWT) range adopted for each of the three ship types is:

	'000 DWT
• Bulk	10 - 70
• Ro-ro	2.5 - 25
• Container	2.5 - 35

Some contract values for vessels outside these DWT ranges were available, however they were few in number and generally varied greatly compared with the contract values for vessels within each size range. For container ship contracts announced during 1977 and 1978, ships above 35000 DWT exhibited a high unit cost. This appeared to be mainly due to large refrigeration units that were fitted to these vessels, to allow them to carry a high proportion of refrigerated containers (commonly called reefers). The mid 1978 unit cost for these high reefer capacity vessels was of the order of $1450 per DWT, which was well above the $860 per DWT observed for smaller vessels around the 30000 to 35000 DWT size range.

By contrast, the few contracts for large bulk carriers of over 100000 DWT reported during 1977 and 1978 exhibited low unit costs compared with bulk vessels within the 10000 to 70000 DWT size range. Unit costs were of the order of $190 per DWT for these large vessels compared with $280 per DWT for a 70000 DWT bulk carrier.

1 The confidence interval is a statistical means of giving both an idea of the actual numerical value that a parameter may have and also an indication of how confident we may be, on the basis of the sample, that we have given a correct indication of the possible numerical value of the parameter.



Legend: Ship data point ⊙
Estimated cost vs deadweight ———
90% Confidence Limits -------

Note: Cost estimates at July 1978

Figure 2.1
Estimated capital cost vs deadweight: bulk carriers

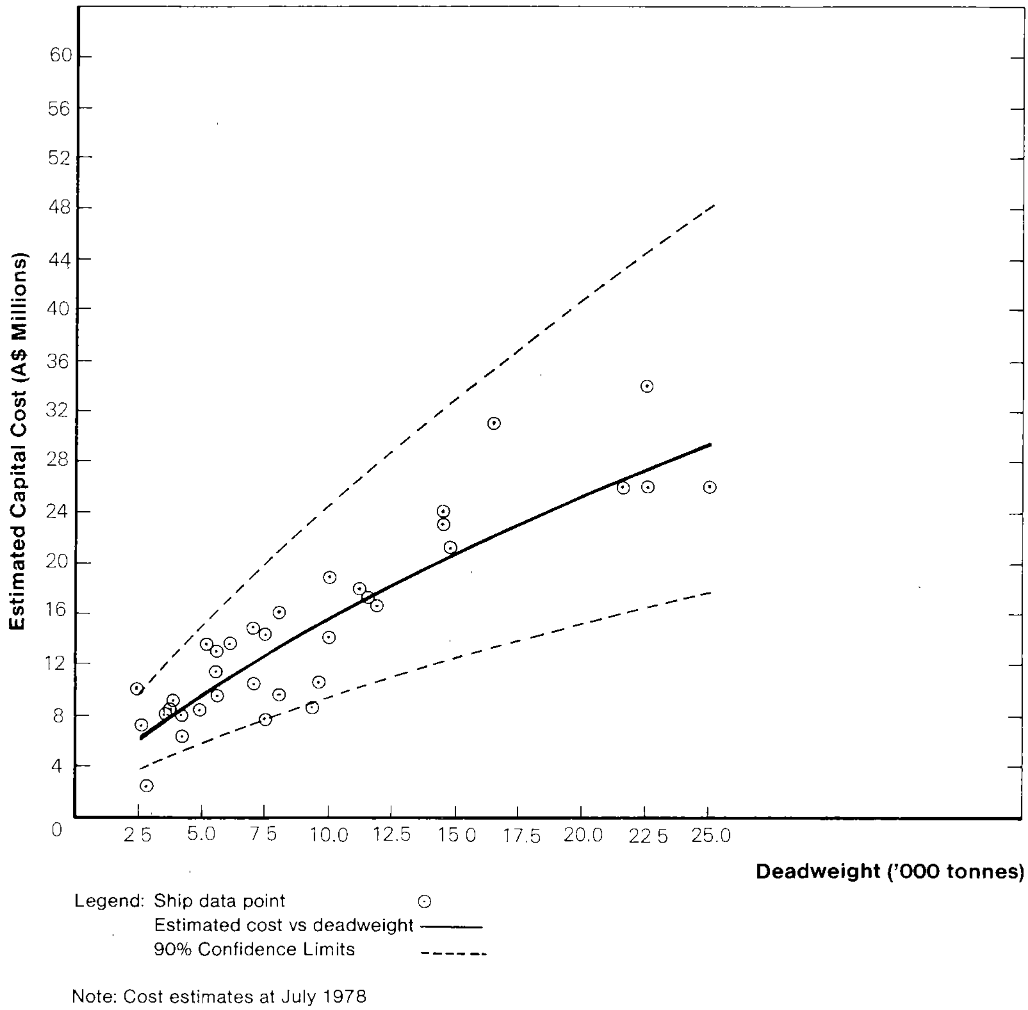
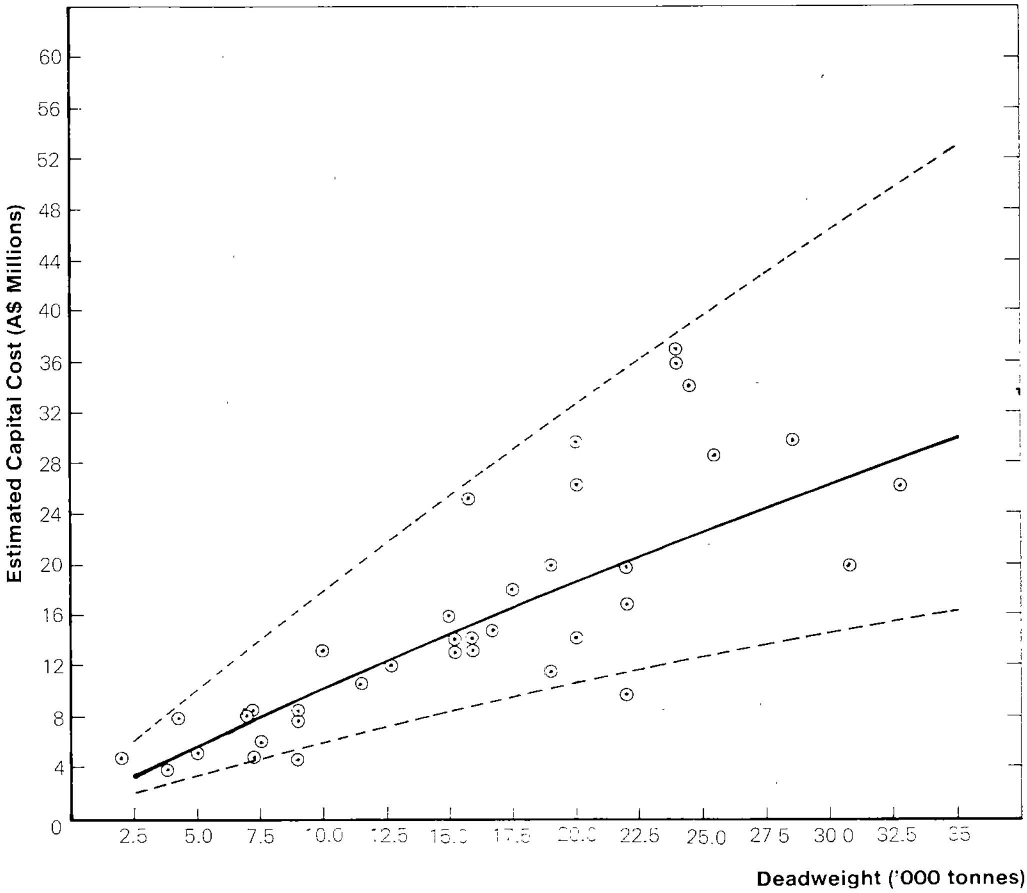


Figure 2.2
Estimated capital cost vs deadweight: ro-ro ships



Legend: Ship data point ⊙
Estimated cost vs deadweight ———
90% Confidence Limits ------

Note: Cost estimates at July 1978

Figure 2.3
Estimated capital cost vs deadweight: container ships

SHIP DAILY CAPITAL COST ESTIMATE

Estimates of daily capital costs for bulk, ro-ro and container ships are presented in Table 2.2. These estimates have been calculated from Table 2.1 by discounting the initial capital cost over 15 years at a rate of 8.8 per cent[1].

TABLE 2.2 - SHIP DAILY CAPITAL COST ESTIMATE: REGRESSION COEFFICIENTS FOR MODEL,[a]
$D=\alpha \cdot (DWT)^{\beta} \cdot \epsilon$

Ship type	α	β
Bulk	506.6	0.6028
Ro-ro	1054.3	0.6942
Container	486.1	0.8528

a. Estimates in $A/day at June 1978, DWT refers to thousands of deadweight tonnes Based on a discounted capital cost at 8.8 per cent per annum over 15 years with 365 days per annum availability. ϵ is the stochastic error term and is assumed to equal one.

Source: Derived from Table 2.1.

In this study the main aim has been to estimate present day operating costs. No account has been taken of inflation. If a long-term analysis is required, or if more recent operating cost estimates are needed, a calculation of the effect inflation may have on the various operating costs would need to be made. Different discount rates to the one adopted in this paper can be used by appropriately factoring the results in accordance with the desired rate.

The daily capital cost has been calculated as 1/365th of the annual cost. This does not allow for downtime due to maintenance and repairs, typically assumed as 15 days per annum but adopts a constant capital commitment throughout the year, regardless of whether the vessel is in or out of service. This assumption lowers the daily cost compared with spreading the capital cost over a 350 day operating period, however the difference is of the order of 4 per cent and can be adjusted if felt necessary.

Both of these daily cost figures could be considered, in an economic sense, to overstate the capital component if the vessel is idle due to a lack of market opportunities. In this situation, the opportunity cost of capital[2] for that vessel could be taken as approximately zero.

This paper assumes that vessels can be employed and that the opportunity cost of their capital is equal to the full capital cost component. Appendix IV details the derivation of the daily capital cost estimates for each ship type.

EQUIPMENT COSTS

A separate cost estimate for the provision of sets of containers for both ro-ro and container ships has been made, as containers are not generally included in vessel contract prices. Other equipment costs for items such as onboard forklifts for ro-ros have been assumed to be included in the contract value. Equipment costs for bulk carriers are negligible and have been taken as zero.

1. In public sector investment analysis, the discount rate is generally chosen to equal the Government long-term bond rate. In mid 1978 this was 8.8 per cent. For private sector investment the discount rate could be much higher to allow for factors such as higher capital servicing charges, risk and uncertainty, or may be lower if subsidised finance is available. The long-term bond rate varies over time and was of the order of 10-11 per cent during 1980.

2. Opportunity cost can be defined in terms of the value of the alternatives or other opportunities which have to be foregone in order to achieve your objective. In the shipping sense if there is no alternative use for a vessel (for whatever reason) then the opportunity cost of capital for that vessel approximates zero.

The daily cost estimates for the provision of containers over the life of ro-ro and container ships are shown in Table 2.3.

TABLE 2.3 - DAILY COST OF PROVIDING CONTAINERS: COEFFICIENTS FOR MODEL,[a]
$A=\alpha+\beta\ .\ (DWT)+\epsilon$

Ship type	α	β
Ro-ro[b]	-106.0	74.7
Container[c]	-265.1	186.7

a. Estimates in $A/day at June 1978, DWT refers to thousands of deadweight tonnes. Constant annuity at 8.8 per cent over 15 year ship life, ϵ is the stochastic error term and is assumed to equal zero.
b. Based on 40 per cent of container ship ancillary costs.
c. Based on container-slot ratio of 1.8, container life 7.5 years.
Source: Based on industry supplied information.

These estimates are based on the provision of sets of containers over the life of a ship, assuming a container life of 7.5 years. A ratio of 1.8 containers per container slot available and a reefer to general purpose container mix of 30 per cent has also been adopted.

Appendix IV discusses the provision of containers and provides the background to the above assumptions.

CHAPTER 3 - BUNKERING OF SHIPS

Fuel consumption by ships is dependent upon engine type and also whether the ship is operating at-sea or in-port. Expressions for daily fuel consumption for main engines as a function of deadweight tonnage for each ship category have been developed for both diesel and steam turbine engines and are detailed in Tables 3.1 and 3.2. These expressions have been developed on the basis of the following specific fuel consumption rates for ships at-sea:

- diesel main engines, 201 grams/kilowatt hour (0.331 lbs/BHP hr) of marine fuel oil (MFO); and
- steam turbine main and auxiliary engines, 292 grams/kilowatt hour (0.481 lbs/SHP hr) of MFO.

Daily at-sea fuel consumption estimates for diesel powered ships is a combination of main engine MFO consumption, plus an allowance for marine diesel oil (MDO) consumption by generators supplying auxiliary power. The daily diesel auxiliary consumption rates have been converted to MFO using the mid 1978 price ratio between the two fuels of 1.5. Diesel and steam turbine engine types have been assumed to operate with mean continuous ratings of 0.87 and 0.93 respectively[1].

All in-port fuel consumption is assumed to arise from on-board power requirements. Consumption resulting from slow steaming and manoeuvring to enter port has not been included because of the variations that can occur from port to port.

Bunker prices used to calculate daily fuel costs have been taken as the average of Sydney and Melbourne prices, quoted in the BP International Bunker Prices Schedule No. 4 of September 1978. A rebate of US$14/tonne for marine fuel oil (MFO) and US$16/tonne for marine diesel oil (MDO) has been subtracted from the September prices to reflect the rebate being offered at that time. Prices at mid 1978 in Australian dollars (after subtracting the rebate) were:

- marine fuel oil $74.25/tonne at 180cSt viscosity; and
- marine diesel oil $111.00/tonne at 11cSt viscosity.

TABLE 3.1 - DAILY AT-SEA FUEL CONSUMPTION ESTIMATE: COEFFICIENTS FOR MODEL[a]
$E=\alpha \, . \, (DWT)^{\beta} \, .\epsilon+\gamma$

Ship type	*Consumption of MFO equivalent[b] by engine type*					
	Diesel			*Steam*		
	α	β	γ	α	β	γ
Bulk	4.65	0.579	3.0	7.19	0.579	0.0
Ro-ro	5.57	0.905	0.0	c	-	-
Container	2.86	1.16	0.0	3.69	1.16	0.0

a. Fuel consumption estimate is in tonnes per day, DWT refers to thousands of deadweight tonnes.ϵ is the stochastic error term and is assumed to equal one.
b. MFO refers to marine fuel oil.
c. Few steam turbine ro-ros are in existence.
Source: Based on individual ship information supplied by operators.

1. The mean continuous rating is the engine output as a percentage of the maximum propulsion power available.

TABLE 3.2 - DAILY IN-PORT FUEL CONSUMPTION ESTIMATE: COEFFICIENTS FOR MODEL,[a]
$F=\alpha+\beta\ .\ (DWT)+\epsilon$

Ship type	Consumption of MFO equivalent[b] by engine type			
	Diesel		Steam	
	α	β	α	β
Bulk	4.5	0.0	9.0	0.0
Ro-ro	1.13	0.44	c	-
Container	0.17	0.52	0.22	0.69

a. Fuel consumption estimate is in tonnes per day, DWT refers to thousand of deadweight tonnes. ϵ is the stochastic error term and is assumed to equal zero.
b. MFO refers to marine fuel oil. For diesel auxiliaries a MDO/MFO price ratio of 1.5 was used. This was based on mid 1978 MDO and MFO prices.
c. Few steam turbine ro-ros are in existence.
Source: Based on individual ship information supplied by operators

Derivation of the fuel consumption estimates together with background information on engine types and fuel grades are given in Appendix V.

Appendix II discusses the change in these bunkering prices over time and also presents fuel costs calculated using prices at January 1980.

CHAPTER 4 - CREWING COSTS

It is very difficult to determine a representative, general crew cost for any particular ship type and size. Not only is there considerable variation in the number of crew on the various ships, but also the distribution of crew members between different trades and ranks varies as do the conditions under which they are engaged. Not only are matters such as travelling allowances related to crew change-over important, but so also are industry wide arrangements such as the Japanese practice of employing personnel on a lifetime basis which leads to a large 'reserve' of seamen with an associated cost to ship operators (Lloyds Shipping Economist, 1981). Such arrangements contrast with those related to employment of mixed nationality crews under flags of convenience which represent the lowest level of crew costs.

Because of the difficulties in obtaining information about overseas practices and the associated difficulties in handling such widely varying practices, the main focus of this paper is on crew costs for Australian ships. Such costs are thought to be at the upper end of the world scale.

Table 4.1 presents crew numbers, wage rates for officers and ratings and additional allowances for typical Australian crewed ships based on data obtained from industry sources. These have been combined to produce annual and daily crew cost estimates. The costs are based on rates and standards prevailing in mid 1978 and on the assumption that all crew positions are continuously occupied and that no overtime payments are involved. Daily crew costs are based on the assumption that crew are engaged on a 365 day per year basis.

Some comment concerning foreign crew costs and a detailed breakdown of Australian coastal and overseas crewing costs are presented in Appendix VI.

TABLE 4.1—CREW COSTS FOR VARIOUS SHIP TYPES[a]

Ship type	*Complement*	*Officers[b]*		*Ratings[c]*		*Additional allowances ($ per ship per annum)*	*Total Crew costs[d]*	
	(No.)	*(No.)*	*(Average wage per annum) $*	*(No.)*	*(Average wage per annum) $*		*(M$pa)*	*($/day)*
Overseas bulk	39	12	37 257	27	29 697	289 800	1.538	4 216
Coastal bulk	39	12	41 157	27	32 797	274 800	1.654	4 532
Overseas ro-ro	37	12	37 257	25	29 697	289 800	1.479	4 053
Coastal ro-ro	37	12	41 157	25	32 797	274 800	1.589	4 352
Overseas container	40	12	37 257	28	29 697	289 800	1.568	4 297
Coastal container	40	12	41 157	28	32 797	274 800	1.687	4 622

a. Australian crewed ships only; all costs at mid 1978 prices.
b. Average officer wage calculated at Chief Officer level.
c. Average rating wage calculated at Able Seamen level.
d. Daily costs based on crew employment of 365 days per annum.
Source: Shipping Industry.

CHAPTER 5 - SHIP INSURANCE

Ship insurance premiums are difficult to model on a basis of ship size, type or other dimensions because of external factors which have a large influence on the premium. From discussions with insurance representatives and the Australian Insurance Council, the major external factors were identified as:

- record of ship operator;
- route sailed;
- commodity carried; and
- size of excess included in the policy.

As a result, insurance rates can vary greatly between identical ships, the premium being calculated in accordance with the ship's parameters and weighted by the major external factors. To overcome these problems of individual policy assessment which are the domain of the ship underwriter, the annual ship insurance premium has been assumed to approximate 1 per cent of the ship's initial capital cost. The reasons for this assumption are that it best describes insurance premiums reported in shipping literature and also assigns higher premiums to the more costly ships. It does not however discriminate on the basis of route, operator or commodity carried.

The insurance estimate adopted represents around 2 to 3 per cent of the total at-sea operating costs for each ship type. Variations in this estimate would have to be substantial to have any effect on total operating costs.

Table 5.1 lists the daily insurance estimates, which have been derived from the capital cost expressions in Table 2.1. Appendix VII provides further background on ship insurance, in particular the types of insurance available and the method by which underwriters determine annual premiums.

TABLE 5.1 - DAILY INSURANCE ESTIMATES: COEFFICIENTS FOR MODEL,[a] $I=\alpha\ .\ (DWT)^{\beta}\ .\ \epsilon$

Ship type	α	β
Bulk	41.32	0.6028
Ro-ro	85.99	0.6942
Container	39.65	0.8528

a. Insurance estimates in $A per day at mid 1978 prices DWT refers to thousands of deadweight tonnes. ϵ is the stochastic error term and assumed equal to one.

Source: Based on ship capital cost estimates.

CHAPTER 6 - REPAIRS AND MAINTENANCE

Repairs and maintenance have been defined to include running repairs whilst the ship is in service, as well as periodic or fixed interval maintenance, survey and damage repairs. Estimates of the stores required for on-board maintenance have been included in the following chapter on victuals and miscellaneous charges.

Numerous factors affect both the amount and the uniformity of repairs and maintenance expenditure. Fixed interval surveys for example, may result in large expenditure in any one survey year and can heavily influence disposal decisions for older vessels. Older ships may also be placed on a minimum maintenance schedule prior to their disposal. To overcome problems of modelling an annual expenditure that can vary greatly from year to year, the annual repairs and maintenance bill over the life of a ship has been assumed constant, and equal to 10 per cent of the ship's annual capital cost component. This assumption agrees with other studies undertaken in this area (Gilman, Williamson & Hughes 1978).

Table 6.1 lists the expressions adopted for repairs and maintenance for each ship type. These costs do not include costs for modifications, conversions or modernisation which may occur over a ship's life. Further discussion on the factors influencing repairs and maintenance expenditure is provided in Appendix VIII.

Total at-sea operating costs are not expected to be sensitive to variations in the repairs and maintenance estimate, since repairs and maintenance contribute to only around 3 to 4 per cent of daily at-sea operating costs. Large variations in the expressions assumed in Table 6.1 would therefore only have a minor impact upon daily operating costs.

TABLE 6.1 - DAILY REPAIRS AND MAINTENANCE ESTIMATES: COEFFICIENTS FOR MODEL,[a]
$M = \alpha \cdot (DWT)^{\beta} \cdot \epsilon$

Ship type	α	β
Bulk	50.7	0.6028
Ro-ro	105.4	0.6942
Container	48.6	0.8528

a. Repair and maintenance estimates in $A per day at mid 1978 prices. DWT refers to thousands of deadweight tonnes ϵ is the stochastic error term and assumed equal to one.

Source: Based on ship capital cost equations.

CHAPTER 7 - VICTUALS AND MISCELLANEOUS CHARGES

A number of housekeeping and other items have been included under this section to finalise the assessment of ship operating costs. The figures adopted stem from Australian industry sources and are quoted in mid 1978 Australian dollars.

A lack of information on the cost of victualling for different crew nationalities and the influence of ship size on stores requirements has prevented any meaningful differentiation between these various alternatives. Costing in this area has therefore been based on Australian vessel figures. Estimates of these figures are presented in Table 7.1.

Administration costs have been excluded because of the difficulty of devising an allocative system for shore based costs between ships in a fleet. Although a budget figure of around $300 per day was quoted by one operator as indicative, these costs have not been included in this analysis. The effect on the operating costs (without fuel) of the exclusion of administration charges, based on the figure above, is to reduce the total daily cost by 1 to 5 per cent, depending on ship size and type.

TABLE 7.1 - VICTUALS AND MISCELLANEOUS CHARGES[a]

Crew size No.	*Victuals ($A000 pa)*	*Stores[b] ($A000 pa)*	*Total per Ship ($A000 pa)*	*($A/day)*
27	54	90	144	395
28	56	90	146	400
29	58	90	148	405
30	60	90	150	411
33	66	90	156	427
37	74	90	164	449
39	78	90	168	460
40	80	90	170	466

a. All estimates are in $A at mid 1978 prices.
b. Stores include deck maintenance materials and major items such as mooring ropes.
Source: Information from Australian operators.

CHAPTER 8 - SUMMARY OF RESULTS

A summary of each of the disaggregate cost elements together with the total at-sea operating costs are shown in Tables 8.1 to 8.3 for a sample of two vessels in each of the bulk, ro-ro and container ship categories. To minimise the tabulations only diesel engined ships with Australian crews for the overseas trade have been included, with operating costs calculated in mid 1978 dollars.

Graphical results showing the at-sea operating costs, for each of the three ship categories using Australian crewed, diesel engined ships are also included as Figures 8.1 to 8.3.

Because of rapidly shifting prices, particularly for bunker fuel and the fact that the base information in this report is shown in mid 1978 dollars, a method of bringing estimates up to present day prices has been provided in Appendix II. The information from that Appendix has been used to present at-sea operating cost estimates for January 1980 for each of the three ship categories. These results are shown in Figures 8.4 to 8.6.

TABLE 8.1—DAILY AT-SEA OPERATING COSTS FOR BULK CARRIERS[a]

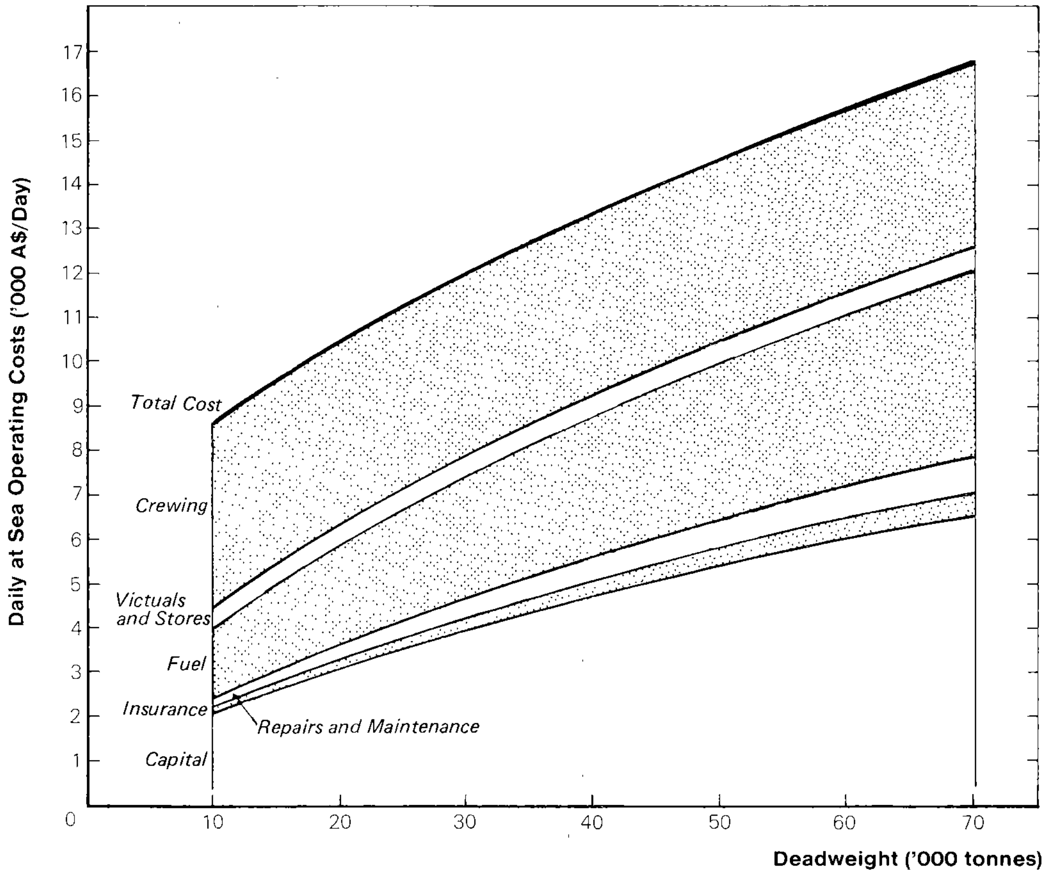
Cost component	*35 000 DWT*		*70 000 DWT*	
	($/day)	*(per cent)*	*($/day)*	*(per cent)*
Capital cost	4 319	34	6 560	39
Insurance	352	3	535	3
Repairs & maintenance	432	3	656	4
Crewing	4 216	33	4 216	25
Victuals etc	460	4	460	3
Fuel at sea	2 928	23	4 263	26
Total	12 707	100	16 690	100

a. Figures are for Australian crewed, diesel engined ships operating in the overseas trade at mid 1978.
Note: Per cent figures have been rounded.

TABLE 8.2—DAILY AT-SEA OPERATING COSTS FOR RO-RO SHIPS[a]

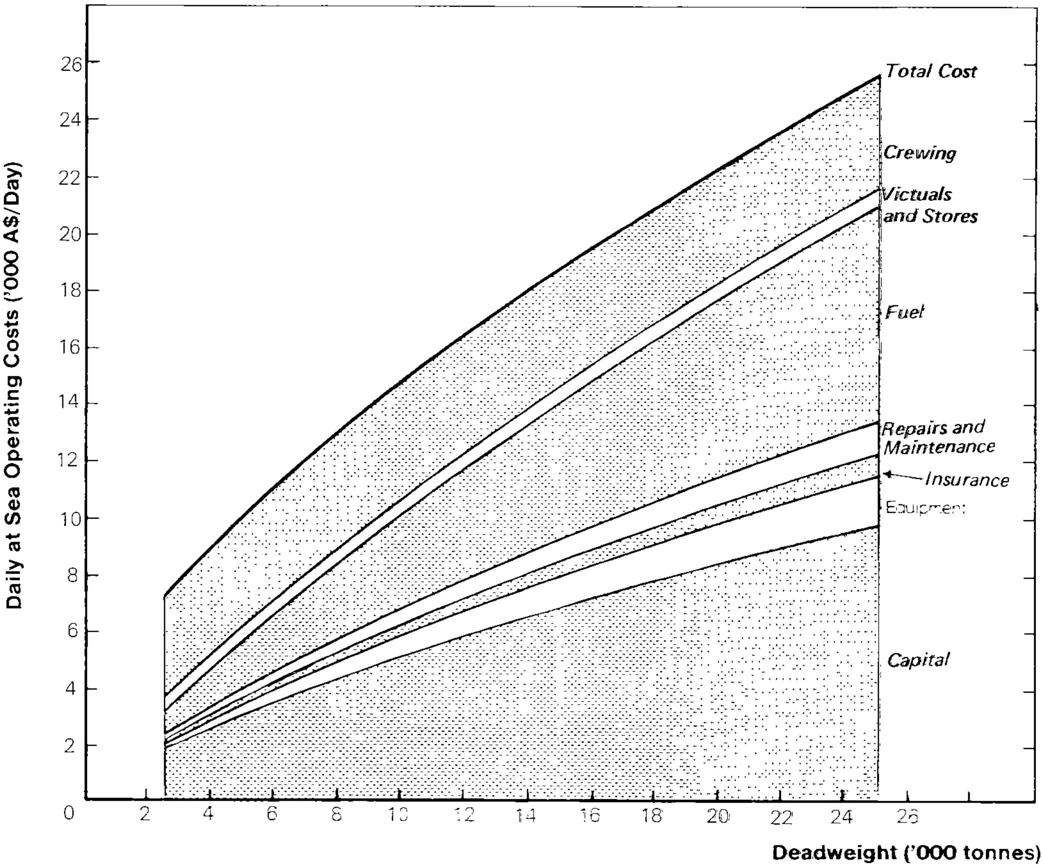
Cost component	*14 000 DWT*		*22 000 DWT*	
	($/day)	*(per cent)*	*($/day)*	*(per cent)*
Capital cost	6 586	37	9 013	38
Equipment - containers	939	5	1 537	7
Insurance	537	3	735	3
Repairs & maintenance	658	4	901	4
Crewing	4 053	23	4 053	17
Victuals etc	449	3	449	2
Fuel at sea	4 506	25	6 783	29
Total	17 728	100	23 471	100

a. Figures are for Australian crewed, diesel engined ships operating in the overseas trade at mid 1978.
Note: Per cent figures have been rounded.



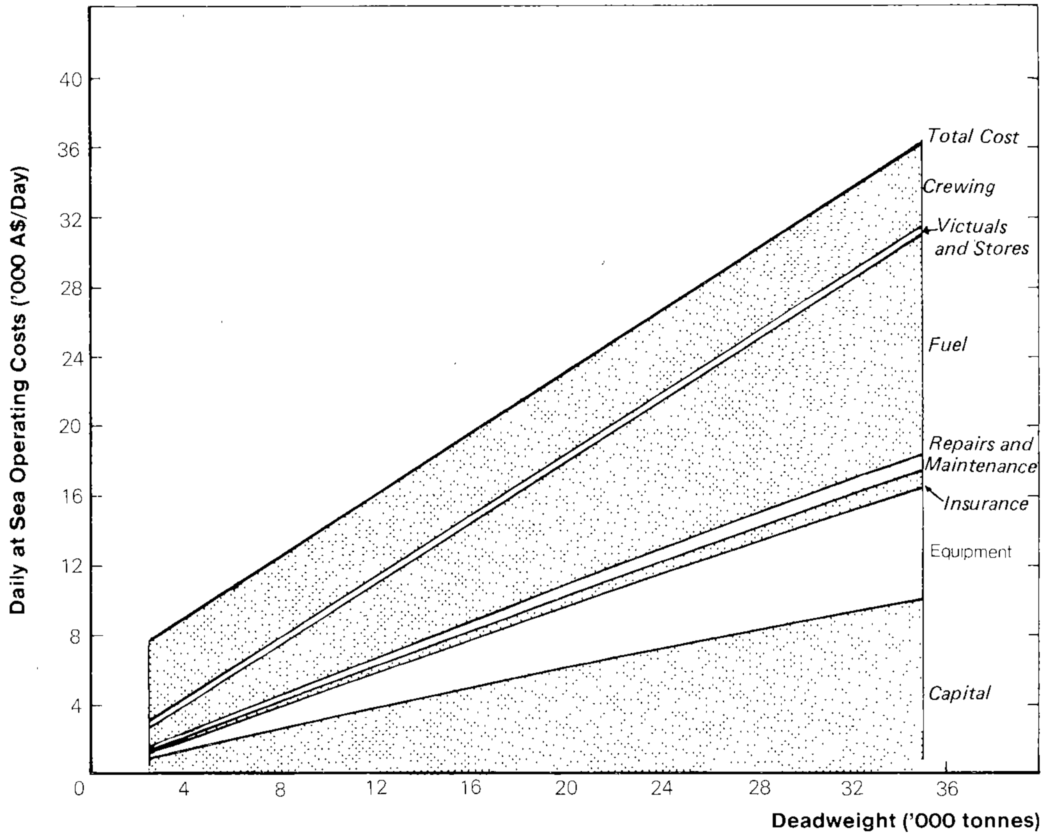
Note: Cost estimates at July 1978

Figure 8.1
Daily at sea operating costs: diesel engined, Australian overseas trade bulk carriers, 1978



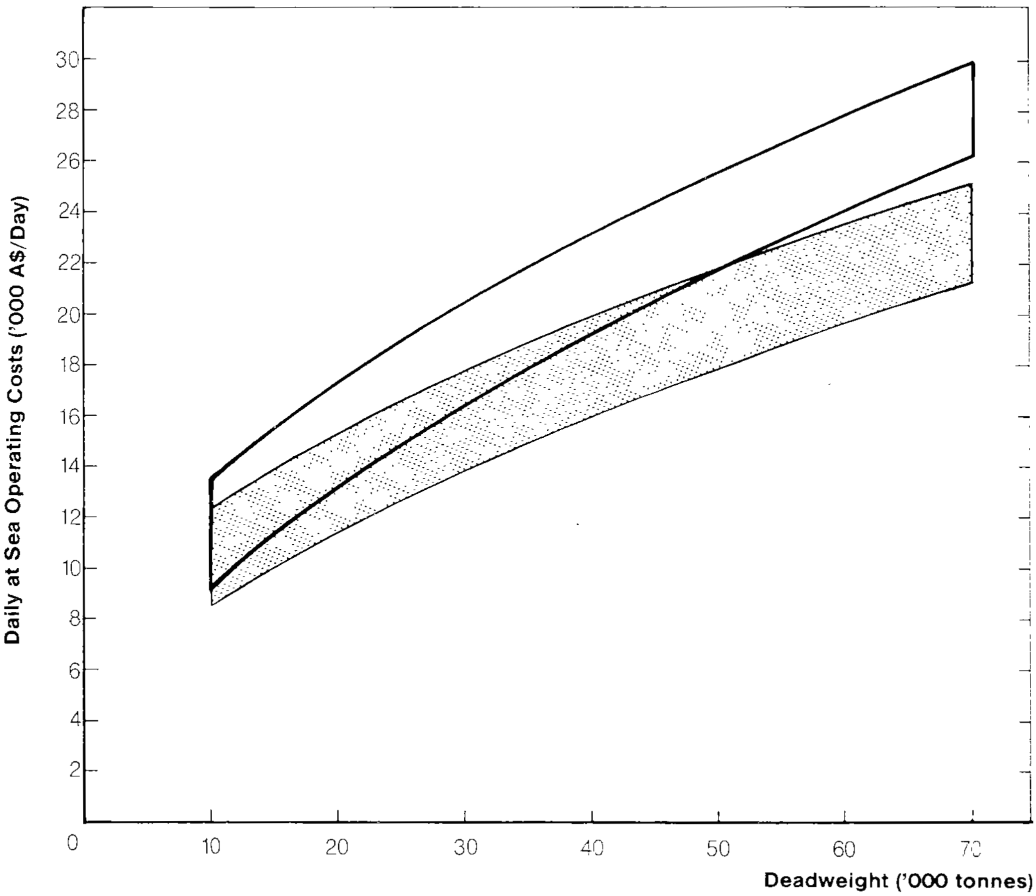
Note: Cost estimates at July 1978

Figure 8.2
Daily at sea operating costs: diesel engined, Australian overseas trade ro-ro ships, 1978



Note: Cost estimates at July 1978

Figure 8.3
Daily at sea operating costs: diesel engined, Australian overseas trade container ships, 1978

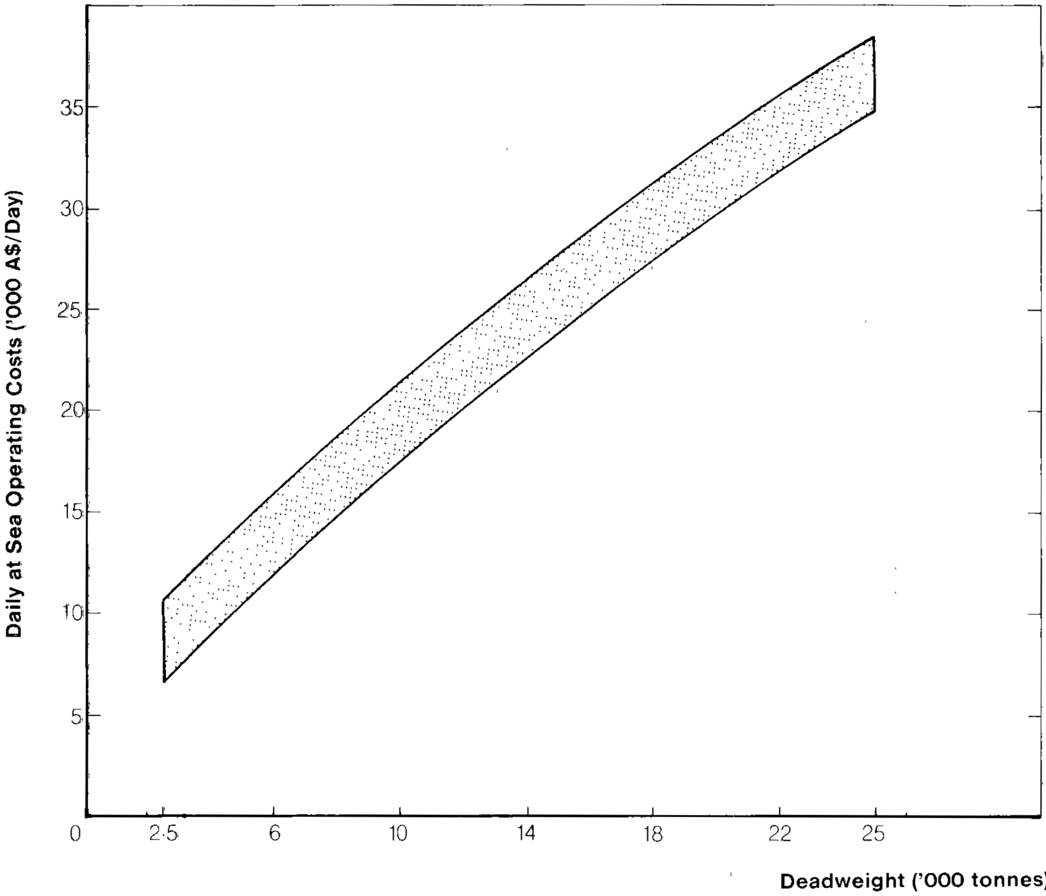


Legend: Range of at sea operating costs, diesel engined ships

Range of at sea operating costs, steam turbine engined ships

Note: Upper limit on each range based on Australian crew rates for coastal trade
Lower limit based on estimated lowest international crew rates
Operating costs at January 1980

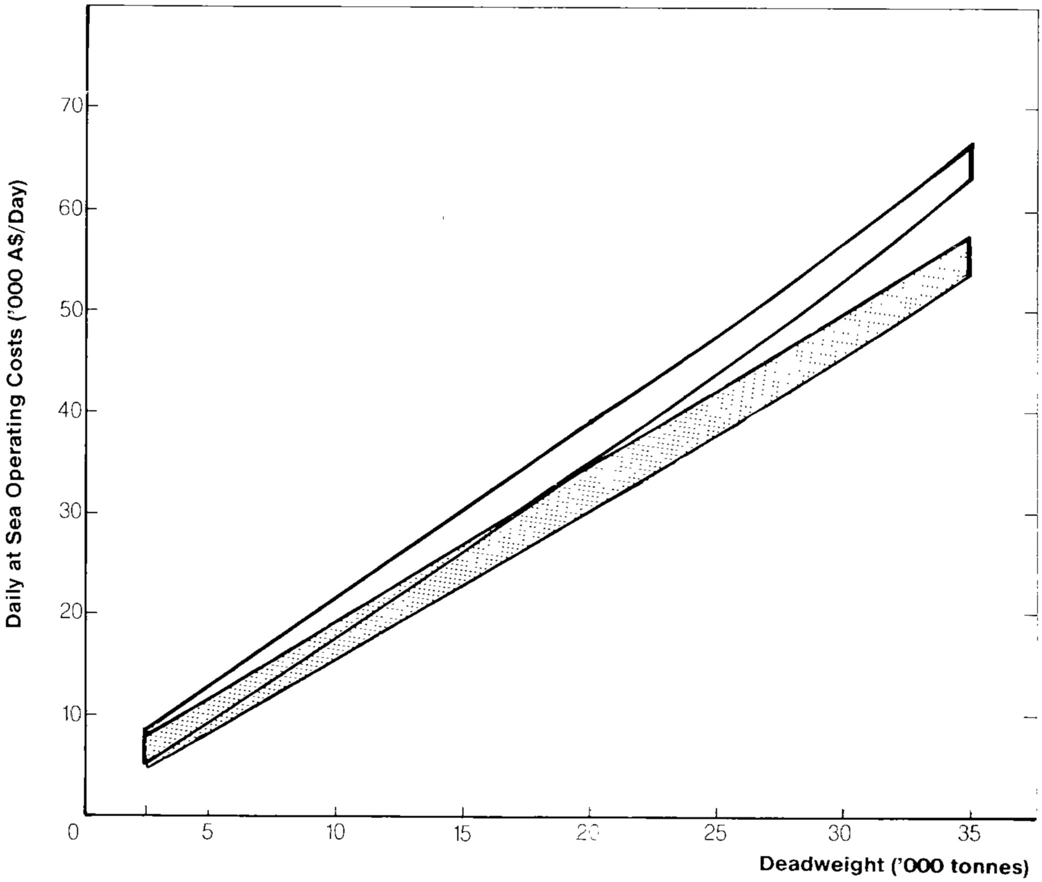
Figure 8.4
Comparison of daily at sea operating costs: bulk carriers 1980



Legend: Range of at sea operating costs, diesel engined ships

Note: Upper limit on range based on Australian crew rates for coastal trade
Lower limit based on estimated lowest international crew rates
Operating costs at January 1980

Figure 8.5
Comparison of daily at sea operating costs: ro-ro ships 1980



Legend: Range of at sea operating costs, diesel engined ships

Range of at sea operating costs, steam turbine engined ships

Note: Upper limit on each range based on Australian crew rates for overseas trade
Lower limit based on estimated lowest international crew rates
Operating costs at January 1980

Figure 8.6
Comparison of daily at sea operating costs: container ships, 1980

TABLE 8.3—DAILY AT-SEA OPERATING COSTS FOR CONTAINER SHIPS[a]

Cost component	*14 000 DWT*		*35 000 DWT*	
	($/day)	*(per cent)*	*($/day)*	*(per cent)*
Capital cost	4 615	27	10 081	28
Equipment - containers	2 349	14	6 269	17
Insurance	376	2	872	2
Repairs & maintenance	461	3	1 008	3
Crewing	4 297	25	4 297	12
Victuals etc	466	3	466	1
Fuel at sea	4 535	27	13 127	36
Total	17 099	100	36 120	100

a. Figures are for Australian crewed, diesel engined ships operating in the overseas trade at mid 1978
Note: Per cent figures have been rounded.

CHAPTER 9 - SENSITIVITY TESTS

The major uncertainty in calculating operating costs lies with the estimation of the capital cost of ships. All other variables are either known or can be estimated with a reasonable degree of preciseness. Sensitivity testing of variables such as insurance, repairs and maintenance and victuals have been discussed in the paper within their relevant chapters. Although each of these variables is considered minor in absolute terms, their derivation in this paper links them to the capital cost estimate and they are therefore affected by variations in this estimate. Their individual contributions to at-sea opèrating costs are generally less than 5 per cent of the daily costs and are considered not critical to this analysis. Sensitivity testing of bunkering and crew costs has not been performed because of the expected robustness of the estimates.

New ship prices can be affected by the state of the shipping market, the level of subsidies offered and other factors. The calculation of daily costs can also vary depending on the discount rate chosen and the period over which the ship is written off. To give an indication of the possible variation in capital costs for the sample of ships used by this paper, a 90 per cent confidence interval for the estimated capital cost has been drawn in Figures 2.1 to 2.3 for each ship type. This interval indicates for a particular value of deadweight tonnage, the range of capital costs within which. with 90 per cent confidence, we might expect a vessel from the sample to lie.

The percentage variation in capital cost within the 90 per cent confidence interval is given in Table 9.1 for a typical bulk, ro-ro and container ship. These figures show that for the sample of ship capital costs used in this paper, the container ship sample exhibits the greatest percentage variation about its mean capital cost. In daily operating cost terms the variation in the capital item within the 90 per cent confidence interval could affect daily costs by as much as 24 per cent for ro-ro ships and by slightly lesser amounts for bulk and container ships.

TABLE 9.1 - SENSITIVITY OF VARIATION IN CAPITAL COST[a]

Typical ship	*Cost estimate*	*Variation about mean cost[b] estimate for ship costs at boundaries of 90% confidence intervals (%)*	
		upper bound	*lower bound*
Bulk	Ship capital cost	+46.2	-31.5
70000 DWT	Total at-sea operating cost[c]	+18.1	-12.4
Ro-ro	Ship capital cost	+63.5	-38.8
22000 DWT	Total at-sea operating cost	+24.0	-14.9
Container	Ship capital cost	+76.4	-43.3
35000 DWT	Total at-sea operating cost	+21.4	-12.1

a. Costs are based on diesel ships manned by Australian crews in the overseas trade at mid 1978.
b. Variation about mean capital cost determined from Table 2.1. Ship capital costs do not include equipment costs.
c. Insurance and repairs and maintenance based on mean capital costs.

Although appropriate discount rates and ship life assumptions can be made to suit a particular analysis, it is difficult to make a robust estimate of ship capital cost, unless the estimate is for a particular ship. Because of the importance of this variable, a discussion of the major factors which determine the price of ships has been included in Appendix III.

APPENDIX I - NAVIGATION, PORT AND CANAL CHARGES

Ship operators are charged for the use of port facilities, canals, navigation aids and are often required to contribute to funds established to combat oil spills and other pollution caused by ships. The method of levying these charges varies greatly between different countries and ports. Specific port charges such as berthage, tonnage, pilotage, canal transhipment, wharfage rates, tug charges and charges for ship domestic services and cranes also vary considerably in their calculation. These charges can be levied on:

- volume or weight of cargo, unloaded or transhipped;
- gross registered tonnage;
- net registered tonnage;
- time in port;
- length of ship;
- wharf type required, and position of wharf; and
- amount of services required.

To estimate these charges on an annual basis a shipper would have to consider:

- the proposed route of vessel, and the time taken to complete the route cycle;
- length of time required in each port and any port movement restrictions;
- amount of cargo expected to be loaded, unloaded and transhipped at each port;
- the type of wharves and special services required; and
- the amount of overtime the company is willing to pay or expect per cycle.

Because of the variations that can occur between different ports, ships and cargoes, no estimate of port charges has been included in the models presented in this paper.

APPENDIX II - PRESENT DAY CALCULATIONS OF SHIP OPERATING COSTS

The components of each ship type's daily operating costs have been adjusted in this appendix to reflect operating costs at January 1980. Graphical presentation of these at-sea operating costs for each ship's size range are shown in Figures 8.4 to 8.6. Each of the cost elements which make up the daily operating costs and the method by which they have been adjusted is discussed below.

The capital cost component of the daily operating cost has been adjusted in two ways. Expressions developed in Table 2.1 have been factored to reflect current prices using the Fairplay hypothetical ship cost indices (Fairplay International Shipping Weekly, 17 January 1980, p46-47). The increase in contract price from June 1978 to the end of 1979 is estimated from the Fairplay indices to be:

- bulk carriers 13%
- ro-ro and container ships 3%

The discount rate has been increased from 8.8 per cent to a level of 10 per cent, mainly to reflect higher current interest rates. The combined effect of the two adjustments has meant a daily capital cost increase over the expressions shown in Table 2.2, of 21 per cent for bulk carriers and 10 per cent for both ro-ro and container ships.

Ro-ro and container ship equipment costs have been adjusted to reflect likely container price increases over the 18 month period to January 1980. These increases have been based on historical trends for prices reported in the Fairplay Shipping Weekly over the period 1970-78. The general purpose (GP) and reefer container prices have over 9 years increased at 12 per cent per annum compound over this period, and this annual figure has been adopted to adjust container prices from Table IV.2. The resultant equivalent container price adopted is $3291. Other assumptions on container life, container-slot ratios and reefer-GP mix ratios have been retained. The discount rate has been increased to 10 per cent.

Ships bunkers show the greatest movement of all the cost categories, with marine fuel oil increasing by just over 100 per cent between September 1978 and January 1980. Prices adopted at January 1980 for the two fuel types are:

	A$ tonne
• marine fuel oil (MFO)	176
• marine diesel oil (MDO)	320

The MDO/MFO ratio of 1.82 has been used to adjust the MDO component of in-port and at-sea fuel consumption components from Tables 3.1 and 3.2 to an equivalent MFO consumption at 1980 prices.

As up to date crew information was not available for January 1980, the costs at mid 1978 have been factored using the consumer price index (Australian Bureau of Statistics 1980). The resultant percentage increase in wages assumed for the 18 month period is 15.

Crew changeover expenses (shown in Table VI.1 under indirect expenses) have been increased by 27 per cent, equivalent to the increase in domestic air fares between Sydney and Melbourne over the 18 month period. This yields an overall increase for Australian crews of the order of 16 per cent to January 1980.

Annual insurance estimates are based upon 1 per cent of the ship's capital cost. As capital cost estimates have been increased in line with the Fairplay hypothetical ship index, insurance estimates for January 1980 have also been increased by that same amount over the mid 1978 values.

The basis of the annual repairs and maintenance expenditure estimate is 10 per cent of the annual capital cost component. Since the increase in daily capital costs were not uniform between ship types, whereas increases in repairs and maintenance costs could be expected to be uniform across ship classes, the capital cost increase were not used as a basis for increasing the repairs and maintenance expenditure. A combination of the average increase in Australian labour rates and the daily capital cost increases for ro-ro and container ships was adopted (ie 12.5 per cent) for all three ship types to represent the expected increase in their repair and maintenance costs.

Victuals and stores, which form only a minor part of daily operating costs have been factored by 15 per cent per annum to match the increase assumed for crew wages.

APPENDIX III—MAJOR FACTORS INFLUENCING THE CAPITAL COST OF SHIPS

By examining the graphs of capital cost versus deadweight (Figures 2.1 to 2.3) the width of the 90 per cent confidence interval can be seen to be broad, being more so for the container and ro-ro samples than for the bulk carrier sample. Factors which contribute to this range of prices can be categorised into ship related factors such as specification and delivery date, financial variables, and market related factors. Each of these factors is discussed in the following sections.

SPECIFICATION

One of the most important influences on capital cost variation between ships of like size in the same category (such as the ro-ro, container and bulk ship categories) is the variation in specification. This is particularly evident in the ro-ro and container market, where rapid development and diversification from the inception of these classes in the 1950s and 1960s has led to a proliferation of hybrid ships which combine the handling systems of both types. Development of the bo-ro (bulk, oil, ro-ro) concept is an example of this type of diversification.

Within pure ship categories, large variations in ship purpose occur. This is particularly evident for ro-ro (Waage Nielson 1975) where there are five recognised categories, each with their own characteristic deadweight range, ramp arrangements and types of utilisation, and yet all embodying the concept of horizontal cargo movement.

Container ships however are built to carry the one type of cargo unit and are otherwise independent of the commodity carried within each box. Important variations occur in the specifications of each ship such as the number of refrigerated slots and hence the size of auxiliaries. Large reefer capacities can demand up to 4500 kW of generating capacity on some ships.

DELIVERY DATE

The time taken from ordering to delivery of a ship has been cited as one means by which some builders, and in particular Japanese yards have maintained an edge in the shipbuilding market. By guaranteeing short construction and delivery times they are able to keep price variations to a minimum, as well as maximise the output of their yards. For this reason delivery time is an important factor in determining both the ship contract price and its final delivery price.

FINANCE

In recent years government intervention on the side of nationalised or private ship yards has resulted in a multitude of subsidies, low interest credit, deferred payments, tax concessions and other financial incentives designed to protect these labour intensive industries (Fairplay International Shipping Weekly, 19 January 1978, pp76-93). As a result, the reported contract prices used in this study are known to be deficient because they cannot be compared on an equivalent resource basis. Some countries such as the USA, Poland, Brazil, Korea and Yugoslavia are known to secure orders at prices well below those of other major ship building countries. For this reason orders reported by shipyards within these five countries have been excluded from this analysis.

MARKET RELATED FACTORS

Overtonnage, especially in the tanker trade and to a lesser extent the dry cargo market, is recognised as a major factor in influencing new ship prices. Currency fluctuations, in particular the shift in relative value of the Japanese Yen and US dollar, can also have significant effects, particularly on the Japanese industry, which is one of the world's leading ship building nations. These factors are examples of the uncertainty and change which can occur across the industry and which can further confound any attempts at capital cost estimation.

USE OF CONFIDENCE INTERVALS FOR CAPITAL COST ESTIMATION

Although the limitations on the capital cost equations have been identified in this appendix, no way of quantifying these effects is presently available. Depending upon the purpose to which the equations are to be put, it may be more appropriate to use higher or lower capital cost estimates from within the confidence interval. Knowledge of ship specification may allow a more appropriate choice if this information is available.

APPENDIX IV - DERIVATION OF CAPITAL COSTS FOR SHIPS AND THEIR EQUIPMENT

DATA GATHERING

Data on reported ship contract prices for bulk, ro-ro and container ship categories was collected from industry sources and shipping literature over a period from January 1977 to October 1978[1]. Most price reports have been gathered from shipping journals, in particular Fairplay International Shipping Weekly (London) and Drewry Shipping Statistics and Economics (London). Ro-ro and container ship prices were also obtained from a Japanese shipbuilder as well as indicative prices from the Shipbuilders' Association of Japan.

All data used in this report are expressed in mid 1978 prices. Individual price reports for ships have been converted to Australian dollars at the date of the report and standardised at July 1978 using Fairplays' hypothetical container and bulk ship indices (Fairplay International Shipping Weekly, 13 July 1978, pp72-73).[2]

Multiple ship orders with a contract sum for two or more ships have been converted to an equivalent single order price using a multiple ship reduction factor (Benford 1967)[3]. These multiple ship orders were particularly evident in the container ship market where sixteen of the thirty eight separate reports recorded were for multiple orders, varying from two up to seven ships. By contrast the ro-ro and bulk ship markets showed a predominance of single orders.

SHIPS' CAPITAL COST EQUATIONS

Regression analyses have been performed to establish whether relationships exist between reported contract prices for each ship type and their typical DWT range. The size range adopted for each ship type were determined by the range of price reports available, and are:

Ship	*Size range (DWT)*
Bulk	10 000 - 70 000
Ro-ro	2 500 - 25 000
Container	2 500 - 35 000

Three separate equations of the following form were examined. These were:

$C = \alpha + \beta \cdot (DWT) + \epsilon$ -linear
$C = \alpha \cdot (DWT)^{\beta} \cdot \epsilon$ -power
$C = \alpha + \beta \cdot \ln(DWT) + \epsilon$ -logarithmic

where C=estimated capital cost
DWT=000' deadweight tonnes
ϵ=stochastic error term

The error term is included to describe any unpredictable randomness in the data. This random error stems from the lack of inclusion of all variables that could have influenced the equation, or through errors in the measurement or recording of the data.

1. Discussion of these contract prices and the factors that affect them is undertaken in Appendix III.
2. Price indices are based on averages from worldwide yards excluding the US, Comecon, Brazil, Korea and Yugoslavia, which are considered to offer prices unrelated to the remainder of the world market.
3. Although it is questionable that this factor applies in this case, it is felt that some recognition should be given to likely economies of multiple orders. These factors, developed by Couch and utilised by Benford, appear to be the only index of this type available.

All three equations gave statistically significant relationships between cost and deadweight tonnage for each of the vessel types. The power function was chosen to represent the ship cost - DWT relationship as it conforms with previous work (Goss 1974) and reflects scale economies, which are generally claimed for larger ships. Table 2.1 in Chapter 2 lists the capital cost equations for each ship type and their statistical coefficients. Figures 2.1 to 2.3 also show curves representing the equations together with 90 per cent confidence intervals about the mean.

One exception to the scale economies claimed for larger vessels is that of large container ships of around 35000 deadweight tonnes and above[1]. Beyond this size region, a step in capital cost reports was observed from a typical range of $850 - $1000 per deadweight tonne for ships below 35000 deadweight tonnes, to price reports in the area of $1450 per deadweight tonne for ships above this size. The reasons for this step appear to relate almost entirely to individual ship specifications. Some ships in this range such as the *Australian Venture* (operated by the Australian National Line) and *Resolution Bay* (operated by Overseas Containers Limited) were designed with high service speeds, twin screw propulsion and large reefer capacities. With specifications of this type a higher price compared with a less sophisticated ship of similar deadweight tonnage can be expected.

Daily capital charges expressed in Table 2.2 have been determined by discounting the capital cost at 8.8 per cent per annum (being the Australian Government long term bond rate at mid 1978) over the 15 year assumed life of each ship type. A utilisation of 365 days per annum has been adopted.

COST OF PROVIDING CONTAINERS

The only equipment costs considered for vessels are those for the provision of standard 20 foot ISO containers over the life of container and ro-ro ships. No allowance for equipment costs has been made for bulk carriers as there are no significant items required by these vessels. The provision of on-board handling equipment for ro-ros has been excluded because equipment is likely to be included in the ships' initial capital cost. Costs of providing other unit load devices such as pallets and trailers, which are commonly used on ro-ro ships, have also been omitted because of a lack of reliable cost information.

Estimation of container costs involves assumptions about the TEU capacity of container and ro-ro ships, container-slot ratios and also the types of containers in use.

TEU capacity of fully cellular container ships

The cargo carrying capacity of container ships, and to a lesser extent ro-ros, is often quoted in TEUs rather than the more traditional deadweight measure. To derive a relationship between these two measures, an analysis of pure, fully cellular container ships listed with Lloyds Shipping Register at May 1977 was undertaken. The resultant linear relationship is shown in Table IV.1. Although the relationship is statistically highly significant, the TEU capacity of a ship may be higher than that derived here because of the allowance by designers for the carriage of empty boxes usually stacked on the weather deck. These empties do not add to the deadweight capacity but are sometimes included in the quoted TEU capacity of a ship.

Container-slot ratio

Due to factors such as the numbers of ships in a particular trade, frequency of call, and the inland turnaround time for containers, more than one set of containers per ship is required for each container service. The ratio of containers to the total TEU capacity of ships in a trade is called the container-slot ratio. Various authors have suggested appropriate values varying from 1.5 to 10 or more depending upon the trade.

1. Commonly referred to as third generation container ships, characterised by a beam of around 32 metres allowing carriage of up to 13 containers across the deck hatches.

TABLE IV.1 - CONTAINER CAPACITY: REGRESSION COEFFICIENTS AND STATISTICS FOR MODEL,[a]
$TEU=\alpha+\beta\ .\ (DWT)+\epsilon$

Ship type	α	β	R^2
Container	-79.1 (-4.00)	55.7 (59.3)	0.92

a. Container capacity measured in twenty foot equivalent units. ϵ is the stochastic error term and is assumed to equal zero. DWT refers to thousands of deadweight tonnes.
t statistics shown in brackets.
Source: (Piko 1981).

The ANLINE service between Australia and East Asia has four ports of call in Australia and five in the Hong Kong - South Korea region. This service operates with six ships and has a container-slot ratio of 1.8. By comparison, the ratio is 1.54 for the Australian Japan Container Line service (AJCL), where there are five ships and two and four ports of call in Australia and Japan respectively. It should be noted however that AJCL leases boxes during peak demand as a means of minimising its container-slot ratio.

A container-slot ratio of 1.8 has been adopted for this paper. This ratio provides a reasonable trade-off between low, leasing augmented ratios and high ratios which are usually associated with short round voyage times. Further discussion on the variation of container-slot ratios with route is given by Edmond and Wright (1976).

Proportion of reefer containers

An estimate of the proportion of reefer containers in use relative to general purpose (GP) boxes is required to estimate the cost of providing container sets. This proportion is heavily dependent on trade and season, and therefore any one figure will not necessarily reflect the characteristics of a particular operation. For the Australia-Europe trade and the Pacific Australian Direct (PAD) service, the ACTA/ANL consortium has a total of almost 14000 slots available on its 10 ships, 5400 of which accept reefers. This represents a 39 per cent maximum reefer capacity for its fleet, but individual ships from that trade have reefer proportions as high as 67 per cent[1]. By comparison, the AJCL service to Japan normally operates with a total of 4350 containers, 31 per cent of which are reefer boxes, although leasing by AJCL during peak periods can alter this proportion.

A reefer proportion of 30 per cent has been adopted for the purposes of calculating container costs over the life of a fully cellular container ship.

Daily equipment costs for container ships

The daily cost calculations for the supply of containers has been based upon container prices which are shown in Table IV.2. These prices have been obtained from industry sources and are expressed in mid 1978 dollars. An equivalent container price has been calculated, based upon the use of overseas built GP containers and insulated reefers with a 30 per cent proportion of reefers. The resultant equivalent price of $3620 per container has been adopted together with an assumed life of 7.5 years and a discount rate of 8.8 per cent. Annual availability has been taken as 365 days per annum with a container-slot ratio of 1.8. The estimate of daily container costs for container vessels is presented in Table 2.3.

Daily equipment costs for ro-ro ships

It has been assumed that ancillary equipment costs for ro-ro ships is limited to the provision of containers. On-board equipment such as fork lifts and tractors have been assumed to be included in the ships capital cost. Other unit load devices commonly used on ro-ro ships such as pallets and trailers have been omitted because of a lack of cost information.

1. Additional reefer boxes can sometimes by carried by using integral reefers or clip-on reefer units.

TABLE IV.2 - CONTRACT PRICES FOR VARIOUS CONTAINER TYPES

Container type	*Contract price A$*
General purpose (overseas built)	2 600
General purpose (Australian built)	3 600
Integral reefer	12 000
Insulated reefer (port hole type)	5 800 - 6 000
Clip on refrigeration units	6 500

Source: Figures from various industry sources at mid 1978.

Utilisation of containers on ro-ro ships has been estimated on the basis of figures from the Scan Carriers fleet (Waage Nielson 1975). By 1975 this company operated five, 22000 deadweight tonne ro-ro ships between Australia and Europe with a total of 4000 GP and 280 reefer containers. At a container-slot ratio of 1.8 this represented an average utilisation of 475 containers per ship for each voyage. Assuming a similar DWT - TEU relationship for ro-ro ships to that shown in Table IV.1 for container ships, an average container utilisation of 40 per cent of that for a similar sized container ship is achieved by the Scan Carrier fleet. Daily costs for the supply of containers over the life of a ro-ro ship have therefore been adopted at a rate of 40 per cent of that for an equivalent DWT sized container ship. The expression for this is shown in Table 2.3. All other assumptions on container life, discount rates, and availability remain the same as that assumed for container ship equipment costs.

APPENDIX V - DERIVATION OF BUNKERING EQUATIONS DESCRIPTION OF ENGINE TYPES

An analysis of engine types for all ships greater than 2000 deadweight tonnes delivered during 1977 is shown in Table V.1. The information presented shows that 95 per cent of all ships completed during that year were equipped with diesel engines. Wide acceptance of this engine type is based upon its superior fuel economy compared with turbine machinery, and its ability (particularly with low speed diesels) to burn the medium to heavy fuel grades which are becoming more commonly available.

TABLE V.1 - SUMMARY OF ENGINE TYPES FOR VESSELS DELIVERED IN 1977

Engine type	*No. of ships delivered*	*Percentage of total no.*	*Average kW rating of Engine*[a]
Slow speed diesel	588	50	10 100
Other diesel	540	45	3 470
Steam turbine	51	4	27 400
Gas turbine	8	1	17 200
Totals	1 187	100	

a. Converted from BHP figures for diesel ships and SHP figures for turbine ships.
Source: Motor Ship, (January 1978).

Medium and high speed diesel engines are favoured in smaller ships, as can be inferred from Table V.1. The main reason for this preference is their relatively low capital cost and small size compared with slow speed diesel engines. This is particularly important in the case of stern ramp ro-ro ships where engines must fit below the rear ramp. A commonly cited disadvantage however is their high lubricating oil consumption. Figures from ANL and General Electric (General Electric) (Australian National Line pers. comm., 1978) indicate that the total fuel bill may be up to 5 per cent higher than for other diesel types, due entirely to lubricant consumption.

Steam turbine plants are generally used by larger ships and in the case of tankers, exclusively in the VLCC and ULCC range[1]. High fuel consumption compared with diesel engines appears to outweigh steam turbine claimed advantages of easier maintenance, compact size, simple automation, ability to burn all grades of fuel and a high power to weight ratio. Increasing oil prices and the development of higher powered diesel engines is expected to further restrict the application of steam turbines high power to weight ratio. Increased oil prices and the development of higher powered diesel engines is expected to further restrict the application of steam turbines to higher powers than is now the case (Buxton 1974).

The use of gas turbine machinery is insignificant and is mainly installed in Liquified Natural Gas (LNG) carriers. The exceptions on the Australian scene are several ships operated by the Union Steam Ship Company of New Zealand and Broken Hill Pty Ltd. Some of these ships are expected to be refitted with diesel engines in the near future. Coal fired turbines are also currently on order by Australian operators for use on the coastal trade.

1. VLCC refers to very large crude carriers typically of 160-620 thousand DWT. ULCC refers to ultra large crude carriers typically of 320 thousand DWT and above.

FUEL GRADES AND TYPES

The two major fuel types used by ships are marine fuel oil (MFO) and marine diesel oil (MDO). MFO is used in main engines, with some auxiliary generating equipment also designed to run on this fuel at heavy loadings. MDO is used mainly for running auxiliaries. Each fuel type commands a different price which is influenced by a viscosity based premium (BP Marine International). At mid 1978, diesel oil exceeded the price for MFO by approximately 50 per cent at most Australian ports.

Fuel viscosity, previously measured in seconds Redwood No 1 at 100 F is now taken in Kinematic Centistokes (cSt) at 50°C. Typical MFO viscosities are in the range 80-180 cSt at 50°C (600-1500 sec Redwood) and vary with type of engine and fuel availability. Auxiliary generating equipment using MDO with a viscosity of around 11 cSt (60 sec Redwood) has been adopted for the purpose of diesel oil pricing in this analysis while 180 cSt MFO (1500 sec Redwood) has been assumed for fuel used in main engines.

Discussions with oil industry representatives point to a continuing trend toward heavier residual oils in the refining process. As a result ship operators will be forced to plan for the eventual use of fuels in the range of 320 cSt (3000 sec Redwood) and above as the lighter grades become unavailable. The slow speed diesel and steam turbine engines currently available are better suited to burn these heavier fuels than are medium speed diesels.

SPECIFIC FUEL CONSUMPTION

Fuel consumption varies in accordance with the type and size of engine, auxiliary power requirements and operating strategies, such as the engine rating and ship speed. An attempt has been made to account for these variations, however the effects of slow steaming has been omitted from the calculations.

Specific fuel consumption rates for diesel and steam turbine engines are listed in Chapter 3 for ships operating at sea. These rates are from industry sources and compare favourably with shipping literature figures. The auxiliary power requirements for diesel engined ships are assumed to be supplied by generator sets using MDO. All steam turbine auxiliary power requirements are assumed to be supplied by using the ships' boilers.

Daily fuel consumption

Daily fuel consumption equations have been developed as a function of ship deadweight. To derive these equations it was necessary to establish a relationship between installed power and deadweight. This was performed using pure ship types listed with Lloyds Shipping Register at May 1977. The resultant power relationship for each ship type is shown in Table V.2.

TABLE V.2 - SHIP POWER ESTIMATES: REGRESSION COEFFICIENTS FOR MODEL,[a]
$P=\alpha \cdot (DWT)^{\beta} \cdot \epsilon$

Ship type	α	β
Bulk	1 104	0.579
Ro-ro	1 223	0.905
Container	566	1.16

a. Power estimates in kilowatts, DWT refers to thousands of deadweight tonnes. ϵ is the stochastic error term and is assumed to equal one.
Source: Piko (1981)

Equations for daily at-sea fuel consumption have been established using the specific fuel consumption rates from Chapter 3 together with the DWT-kW equations from Table V.2. The result is a series of equations for each ship and engine type, as a function of their deadweight, giving ship fuel consumption in tonnes of MFO per day (Table3.1). An allowance for auxillary fuel consumption for diesel powered vessels has also been incorporated in Table 3.1

In-port fuel consumption stems from the operation of plant to supply auxiliary power requirements. The power requirements and the fuel consumed by ships in-port varies markedly depending upon the ship and engine type. Ships fitted with diesel propulsion derive their in-port power from diesel generator sets, which can consume up to the order of 18 tonnes per day for large container ships with high reefer capacities. By comparison, steam turbine ships take their auxiliary power requirements direct from the ships' boilers which are rarely shut down during port calls. This can result in fuel consumption rates for steam turbines of the order of two to three times higher than diesel powered ships with similar in-port auxiliary power requirements.

Auxiliary power requirements for container ships have been based on an assumed requirement of 1.905 kg/hr of MDO per reefer unit on board, plus an additional 0.6 tonnes of base requirements[1]. On a daily basis this has been expressed as a function of DWT by assuming a 30 per cent reefer capacity for each vessel, which is in line with previous assumptions. Auxiliary power requirements for bulk carriers have been taken as constant, independent of ship size. Ro-ro ship requirements have been estimated from actual consumption figures. Table3.2 lists the daily fuel consumption figures for ships in-port which are again based on industry sources. These figures refer to the at-berth situation and therefore do not explain or take into account consumption as a result of manoeuvering to enter port, which for this report's purposes has been assumed as negligible.

1. Figure derived from discussions with various industry sources.

APPENDIX VI - FACTORS INFLUENCING WAGE COMMITMENTS FOR AUSTRALIAN AND FOREIGN MANNED SHIPS

CREWING ASSUMPTIONS

Crew costs for each of the ship types shown in Table 4.1 are subject to a number of averaging assumptions.

The crew size selected for each ship type can be regarded as representative only and has been assumed to be independent of ship size within the overall range of this paper.

Similarly the modelling of crew wage costs is based on a simple division into officers and ratings with the former represented by Chief Officer grade and the latter by Able Seaman grade. Clearly, for Australian ships, it would be feasible to use a much finer classification, but the present breakdown is regarded as adequate for the purposes of this paper and makes possible some comparison with foreign flag ships, for which data is difficult to obtain.

AUSTRALIAN CREWING COSTS

A detailed breakdown of wage commitments for a typical Australian manned ship is shown in Table VI.1. The costs shown include both direct expenses due to salary and recreation leave for Chief Officers and Able Seamen as well as total indirect expenses resulting from long service, crew changeover and other allowances for the ship.

Crew changeover expenses include first class airfares for transporting crews to and from changeover ports, and have been estimated at $85000 per annum for coastal ships and of the order of $100000 for ships in the overseas trade. Recreation leave has been included at a rate of 0.8 days leave for each day of service in the overseas trade, and on a one for one basis in the coastal trade.

FOREIGN SHIPS

As indicated in Chapter 4 it is very difficult to establish crewing costs for foreign flag vessels which are directly comparable with those of Australian ships.

Traditionally, crew numbers for Australian and British ships have tended to be higher than for equivalent Scandanavian or Japanese manned ships, and these, in turn, have been higher than under some other flags. Similarly, pay rates for various grades on Australian ships have tended to be higher than for foreign ships. However, the impact of these factors on final costs is not simple to calculate since it depends on the distribution of numbers between grades on particular ships as well as on some aspects of terms of engagement. Basic arrangements such as leave entitlement, superannuation, special allowances, change-over arrangements, etc are important elements for which data on foreign crews was not to hand at the time of writing this paper.

Wider questions associated with industry structure in different countries also makes direct, general comparison hazardous.

Based simply on the differences in wage rates applying in 1978 it would appear that the lowest international crewing might be of the order of 30 per cent of Australian costs, and this figure was used for the preparation of Figures 8.4, 8.5 and 8.6.

TABLE VI.1 - DETAILED ANNUAL WAGE COMMITMENT FOR A TYPICAL AUSTRALIAN MANNED SHIP[a]

	Direct expenses ($ per crew berth per annum)			
	Ratings		*Officers*	
	Overseas trade	*Coastal trade*	*Overseas trade*	*Coastal trade*
Annual salary	15 500	15 500	19 500	19 500
Payroll tax	1 395	1 395	1 755	1 755
Keep and accommodation	402	402	402	402
Recreation leave	12 400	15 500	15 600	19 500
Total direct expenses	29 697	32 797	37 257	41 157

	Indirect expenses ($ per ship per annum)	
	Overseas trade	Coastal trade
Compensation	10 800	10 800
Officers superannuation	32 000	32 000
Crew superannuation	36 000	36 000
Officers long service	20 000	20 000
Crew long service	11 000	11 000
Officers study leave	15 000	15 000
Cadet allowance	2 000	2 000
Clothing	2 000	2 000
Attendance	4 000	4 000
Crew changeover	100 000	85 000
Sundries	57 000	57 000
Total indirect expenses	289 800	274 800

a. All figures in mid 1978 dollars. Ratings at Able Seamen level & Officers at Chief Officer level.
Source: Industry discussions.

APPENDIX VII - BACKGROUND ON SHIP INSURANCE PREMIUMS

BACKGROUND

The insurance equations adopted in Chapter 5 are based upon a percentage of the ships initial capital cost. This type of expression is common amongst shipping literature (Drewry 1977) (Gilman, Maggs and Ryder 1977) and is adopted because of the difficulty of using the insurance underwriters approach. The underwriters approach usually involves the calculation of three separate premiums known as: hull, protection and indemnity (or club), and war premiums. Each premium is based on a different assessment method, related to the type of risk involved. A brief outline of each of the three premiums and the basis for their calculation is set out below.

HULL INSURANCE

Hull insurance is the most important of the three and covers loss and damage as well as liability in the case of a collision. Its premium is based on the insured value of the ship and also any excess or deductable amount agreed to. The insured value will vary in accordance with factors such as owners' record, ship age and route, and as a result the market value of the ship does not always correlate with that of the insured value.

Stromland (1977) states that hull insurance is divided into total loss and average premiums where the total loss premium is a fixed percentage of the ship's insured value. The average premium can be calculated using the ship's cubic number (CN) and by multiplying this by a rate per CN. These premiums are added together and then divided by the insured value, to give the rate per cent for the ship. Hull policies often have an excess or deductable amount which the shipowner agrees to bear when making a claim. The size of this excess has an effect on the premium paid. From discussions with representatives of the insurance industry, a range of typical rate per cent figures by ship type are shown in Table VII.1. These figures are supported by an industry body, the Australian Hull Pool of the Insurance Council of Australia, who also supplied a similar rate per cent range. The Hull Pool quoted a typical hull excess figure to be in the range of $15000 to $50000.

PROTECTION AND INDEMNITY (P&I CLUB) INSURANCE

This insurance covers shipowners legal liability in cases of loss of life and injury to third parties, cargo damage and oil spillage. Hull insurance and P&I combine to cover all liabilities. Calculation of the P&I premium is based on the ships gross tonnage as well as owners record and route. Deductables also apply to this type of insurance. P&I risk is insured through P&I clubs which are formed by groups of ship owners. The premium is determined by the number and size of claims within the club and consists of a first call (or initial premium) followed by additional premiums should claims exceed paid up premiums. Estimates for P&I rates are shown in Table VII.1.

WAR INSURANCE

This covers war damage as well as damage resulting from embargo, civil war, revolutions, commotions, strikes, seizures and sabotage. It is based on insured value with a rate that varies from 0.035 to 0.05 per cent depending on the area of operation of the ship. Table VII.1 also includes war insurance rates.

INTERPRETATION OF RATE PER CENT FIGURES

Although Table VII.1 gives an estimate of typical rates, a deeper knowledge of the factors that contribute to this calculation such as the rate/CN, per cent rate for total loss content and the effect of deductables are necessary before actual insurance premiums can be calculated. This is the domain of the underwriter and is well beyond the scope of this paper. For this reason the ship insurance estimates adopted in this paper reflect those adopted by other shipping studies.

TABLE VII.1 - RATE PERCENT FIGURES FOR SHIP INSURANCE

(percentage value per annum)

Ship type	*Hull rate*	*P&I rate*[a]	*War rate*	*Total premium*
Fully cellular container	0.6-1.0	0.45-0.75	0.035	1.09-1.79
Ro-ro	0.9-1.2	0.68-0.9	0.035	1.62-2.14
Bulk & tankers	1.0-1.7	0.5-0.85	0.035	1.54-2.59
General cargo	0.5-2.0	0.375-1.5	0.035	0.91-3.54

a. P&I rates assumed as 50 per cent of hull rate for bulk carriers and tankers, 75 per cent for all other ship types.
Source: From discussions with insurance industry at mid 1978.

APPENDIX VIII - FACTORS AFFECTING REPAIRS AND MAINTENANCE EXPENDITURE

Repairs and maintenance expenditure can be categorised into the three components of hull, machinery, and survey and docking. Little information is available from shipping literature on these components, however some studies do list figures for maintenance to ships' main engines. Typical annual rates for this maintenance are of the order of US$5/BHP for diesel engines (The Motorship 1977) and US$75000 for steam turbine plants (General Electric).

Survey and docking is usually acknowledged as resulting in an annual down time of 15 days, leaving a corresponding revenue earning period of 350 days per annum. Dry docking accounts for around half of this time and is performed at 18 month to 2 year intervals for Australian ships. Typical charges for a 10 day docking at selected yards in Australia, Japan, Singapore and Canada vary from $A20000 - 70000 depending on the size of the ship (Department of Transport Australia 1977).

Due to the variation in the small number of repair and maintenance reports for individual ships that have been obtained, no attempt has been made to describe this data. The major reason for this variation is that repairs and maintenance requirements change over the life of a ship, and therefore average figures that are selected from a narrow sample can produce biased results.

As a result, an expression for total annual repairs and maintenance has been adopted from shipping literature (Gilman, Williamson & Hughes 1978) and is based on 10 per cent of the ship's annual capital cost component. This assumption ensures a positive relationship between ship size and maintenance cost and also differentiates between the ship types in proportion to their original capital outlays. Table 6.1 lists the expressions for repairs and maintenance for each ship type, on a daily basis.

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ABBREVIATIONS AND TERMS

ACTA	ACTA Pty Ltd
AJCL	Australian Japan Container Line
ANL	Australian National Line
BHP	Brake horsepower. It is the power (in horsepower) measured at the crank shaft coupling by means of a brake.
Deadweight	The total weight in tonnes that a ship carries at its summer loadline draft. It includes cargo, fuel, water in tanks, stores, baggage, passengers, crew and their effects but excludes water in boilers.
GP	General purpose container
ISO	International Standards Organisation
MCR	Mean continuous rating. It is the engine output as a percentage of the maximum propulsion power available.
MDO	Marine diesel oil
MFO	Marine fuel oil
OCL	Overseas Containers Limited
PAD	Pacific Australia Direct
Reefer	Refrigerated container
sfc	Specific fuel consumption measured in grams per kilowatt hour
SHP	Shaft horsepower. It is the power transmitted through the shaft to the propeller. It is usually measured as close inboard to the propeller as possible.
TEU	Twenty foot equivalent unit. Used to describe a 20ft x 8ft x 8ft ISO container.
Tonnage (Gross and Net)	Is a measure of internal volume of a ship where 100 cubic feet is assumed equivalent to 1 ton. Gross tonnage (GRT) includes the ship's internal volume excluding double bottom, peak and deep water ballast tanks, open ended poop, bridge or forecastle, certain light and air spaces, the wheel house, anchor and steering spaces, toilets and certain passenger spaces. Net Tonnage (NRT) is GRT less crew and officer spaces, chart room and a percentage of the machinery spaces.