Freight Transport to North West Australia, 1975 - 1990

Report

The rapid development of mining in the Pilbara region of north west Australia has already increased the transport task in the region and is expected to increase it much more. In the past, there has been little land transport to the north west, and the major service has been by sea. In the fluid situation generated by rapid development, it is important to ask how the freight task should be performed in future, whether the shares carried by the various transport modes should be changed and whether there should be radical changes in the whole transport system to the region. These are the questions that this report sets out to answer.

BUREAU OF TRANSPORT ECONOMICS

FREIGHT TRANSPORT TO NORTH WEST AUSTRALIA 1975 to 1990

AUSTRALIAN GOVERNMENT PUBLISHING SERVICE

CANBERRA 1973

FOREWORD

The rapid development of mining in the Pilbara region of north west Australia has already increased the transport task in the region and is expected to increase it much more. In the past, there has been little land transport to the north west, and the major service has been by sea.

In the fluid situation generated by rapid development, it is important to ask how the freight task should be performed in future, whether the shares carried by the various transport modes should be changed and whether there should be radical changes in the whole transport system to the region. These are the questions that this report sets out to answer.

The report is largely the work of the Operations Research Branch of the BTE, under the direction of Mr. J.C.M. Jones. The team leader was Mr. J.S. Latham, OBE, and his principal assistants were Mr. P.T.A. Riddy and Mr. G.R. Carr. Considerable effort went into developing a preliminary network analysis, a computer simulation of ship operations and a complex linear programming model of land transport logistics. The report does not concentrate on these techniques, but rather on the verification of source data and the interpretation of results to establish investment possibilities over the sixteen years covered by the study.

The Bureau of Transport Economics acknowledges the assistance received from Commonwealth Departments, West Australian State Government Authorities, and commercial enterprises.

J.H.E. TAPLIN
Director

Bureau of Transport Economics,
Canberra, A.C.T.
May 1973

TABLES

PAGE

FIGURES

SUMMARY

This report presents the results of a study of the transport needs arising from development in the Pilbara and Kimberley regions of north west Australia.

A standard gauge rail link between the West Australian Government system and one of the new standard gauge iron ore lines was found to be as cheap a way of meeting the transport needs of the Pilbara as either shipping or lower levels of railway development. To the extent that the Pilbara Industrial Complex is likely to be established, a standard gauge link becomes an increasingly better choice from the community point of view. Should such a choice be made then the shipping service to the Pilbara would gradually become redundant, but ships of the West Australian State Shipping Service (WASSS) would continue to be an economical way of serving the Kimberley and Darwin.

In the past, WASSS met most of the transport needs of the north west regions, but its share of the Pilbara transport task has now declined. In order to increase its capacity and efficiency, WASSS has re-equipped with four relatively modern unit load ships. These are second hand vessels, imported on the understanding that they would be re-exported within five years or that arrangements would be made for their replacement with Australian built vessels.

The time frame of the study was the period 1975-1990. The criterion was the total discounted resource cost of the transport system. This is the cost to the community as a whole and therefore excludes all subsidies and taxes but includes all the allocable costs of road, rail and port construction and maintenance. Past capital investments have been taken as sunk.

The transport requirements of the area over the study period were estimated by taking into account present and future developments, but initially excluding the exploitation of North West Shelf gas. An additional more approximate projection was made of developments arising out of the proposed Pilbara

Industrial Complex, based on low cost power produced from natural gas.

Some road construction and upgrading are already planned for the region. It was established in this study that, for the freight transport task alone, major construction or upgrading beyond current plans was not economically justified. The evaluation therefore concentrated on a range of ship and rail alternatives.

Four ship types were examined:

- Unit load
- Roll on/Roll off
- Hybrid container (containers and unit loads)
- Lighter aboard ship (LASH).

Unit load was found to be the least cost type. Irrespective of the proportion of the Pilbara freight carried by sea, the optimum size was 6,000 tons deadweight and speed 14 knots.

Five railway options were considered. These ranged from some renewal and upgrading of the present State system, terminating at Geraldton on the Midland Railway and Meekatharra on the Northern Railway, through new line construction to close the gap between Meekatharra and the end of the Mt Newman ore railway, to a standard gauge link from Perth to the Pilbara via Geraldton and Mt Newman. Within these options, a range of general freight capacities was examined, from the present 160,000 net tons per annum to 750,000 net tons, more appropriate to the Pilbara Industrial Complex. Further variations were introduced by allowing for phased railway development in step with the growth of the transport task. Thus a large number of options were evaluated against the least cost criterion. This was done by linear programming.

The main findings were:

Many of the ways of meeting transport needs in the Pilbara, under the present pattern of development, had total resource costs within a few percent of the minimum. These options included unit load ships to cover a range of sea shares of the transport task from 80% to zero, upgrading of the existing rail system and new rail construction to close the Meekatharra - Mt Newman gap.

However, rail transport clearly offered the least cost choices for the higher tonnages required by the Pilbara Industrial Complex. Among the better options was standard gauge construction from Geraldton to Mt Newman. At this level of industrial development, possible backloading opportunities, not accounted for in this study, would enhance the advantages of rail.

CHAPTER 1. INTRODUCTION

Until recent years the pastoral industry and some limited mining activities in the Pilbara dominated the transport needs of the north of Western Australia. Because of the remoteness of the region from markets and the dispersion of the centres of production, sea transport has suited the general development of these activities. Even so, the region did not become attractive to private shipping companies and the West Australian State Shipping Service (WASSS) was established with small multi-purpose vessels to fulfil the task.

Over the past decade, the iron ore mining industry of the Pilbara has flourished with production from the mines being primarily directed towards overseas and interstate markets. In order to establish plant capable of the high rates of production necessary at these mines and to serve the increasing populations at the ports and mine towns, a fast, high-capacity transport system had to be developed. Air services to the area also were improved so that now the majority of intrastate passengers and mails travel by air. In this period WASSS has faced a number of difficulties:

- loss of general cargo and passengers to inland transport
- rising costs of operation and of replacing an aged and inefficient fleet
- low rate of return on funds.

To offset these difficulties, proposals were put forward in 1969 to re-equip WASSS with Lighter-Aboard-Ship (LASH) vessels which, by discharging cargo lighters having a capacity of approximately 100 tons, can achieve rapid turn-round. Because of high tender prices, the LASH proposals were not accepted, but in 1971 approval was given for the importation of two ex-Cunard cargo ships, 'Parthia' and 'Medea', on the understanding that the government of Western Australia would place orders for two replacement vessels from Australian shipyards within five years and that 'Parthia' and 'Medea' would then be re-exported.

Two additional unit load ships 'Trans Ontario' and 'Trans Michigan' have since been purchased to enter service in 1973. The approval to import these ships also included the replacement proviso. Table 1.1 summarises vessel characteristics for the imported ships, and Table 1.2 shows voyage statistics.

Arising from discussions at the time of the earlier importation, the Minister for Shipping and Transport agreed that the services of the Bureau of Transport Economics would be made available to undertake a transportation study of the north west. While the primary purpose was to determine the nature, size and number of replacement vessels to meet the future transport requirements of the area, the study was not to be confined to sea transport. The study has been conducted in co-operation with the Western Australia Director-General of Transport. During the course of the study, a new proposal for the development of the Pilbara was issued by the West Australian Government (Annex A). The transport implications of the Pilbara proposal have been incorporated, in a preliminary way, into the study as a secondary evaluation.

Except for a very small quantity of urgent high value freight, air transport is not a contender for a share of the goods traffic.

1.1 AIM AND SCOPE OF THE STUDY

The aim of the study has been to describe the future transport requirements of the area and from these to evaluate alternative transport systems to serve the north of Western Australia by land and sea.

TABLE 1.1 - WEST AUSTRALIAN STATE SHIPPING SERVICE:
DETAILS OF VESSELS, CURRENT UNIT LOAD FLEET

		MV 'Wambiri'	MV 'Beroona'	MV 'Trans Michigan'	MV 'Trans Ontario'
Register Particulars					
Gross registered	tons	5,149	5,149	6,425	6,466
Net registered	tons	4,028	4,028	4,042	4,028
Deadweight	tons	7,444	7,444	7,941	7,946
Powering Particulars					
Service speed	knots	16	16	16	16
Service power	hp	7,700	7,700	7,900	7,900
Heavy fuel usage at sea	tons/day	19.893	19.893	21.037	21.037
Light fuel usage, sea and port	tons/day	1.572	1.572	1.633	1.633
Cargo Carrying Capacity					
Bale cubic	'000cu ft	385	385	407	407
Stowage rate	cu ft/ton	80	80	80	80
Cargo deadweight	tons	4,810	4,810	5,090	5,090
Service History					
Construction date		1963	1963	1963	1963
Delivery to WASSS		Sept.1971	Oct.1971	Feb.1973	Feb.1973
Order date for replacement vessel		Sep.1976	Sept.1976	Feb.1978	Feb.1978
Cost Data					
Capital cost for insurance purposes	$m	2.5	2.5	3.0	3.0
Estimated resale values at end of year: 1976	$m	0.95	0.95	1.30	1.30
1978	$m	0.69	0.69	1.05	1.05
1980	$m	0.43	0.43	0.08	0.08
Effective Crew Complement		30	30	30	30

Source: West Australian State Shipping Service

NOTE: 'Wambiri' and 'Beroona' are the current names given to the 'Parthia' and 'Medea'.

TABLE 1.2 - WEST AUSTRALIAN STATE SHIPPING SERVICE:
SUMMARY OF VOYAGE CHARACTERISTICS, CURRENT UNIT LOAD FLEET

Voyage characteristic		MV 'Wambiri' MV 'Beroona'			MV 'Trans Michigan' MV 'Trans Ontario'		
		Bustop (a)	Shuttle (b)		Bustop (a)	Shuttle (b)	
		All ports	Pilbara	Kimberley	All ports	Pilbara	Kimberley
Speed	knots	16	16	16	16	16	16
Trip time	days	25.13	19.11	24.66	25.19	19.88	25.44
In port time	days	14.74	14.06	14.40	15.52	14.84	15.18
Trips (annual)		13	18	14	13	17	13
Annual capacity	tons	56,290	77,940	60,620	59,540	77,860	59,640

(a) 'Bustop' refers to a call on the northbound voyage at each port from Dampier to Darwin, then return direct to Fremantle. (b) 'Shuttle' refers to calls on the northbound voyage only at ports in the region designated, then return direct to Fremantle.

NOTE: 'Wambiri' and 'Beroona' are the current names given to the 'Parthia' and 'Medea'.

The geographic limits of the study are the State of Western Australia north of an east-west line through Mullewa. The time frame is 1975-1990. Routes of existing sea, rail, and road transport systems are illustrated in Figure 1.1.

The results of the study are expressed in the form of costs of sets of alternative transport systems made up of various combinations of modes (sea, rail, and road) and alternatives within these modes. The possibility that WASSS may not have a role in the future transport system is included.

The study was concerned almost exclusively with supplies for people and industries in the area. Mining production is exported directly and rural production is small in volume, so that there is negligible opportunity at present for back loading. A summary of recent distribution patterns is shown in Table 1.3.

FIGURE 1.1 - ROUTES OF EXISTING SEA, RAIL AND ROAD TRANSPORT SYSTEMS TO THE NORTH OF WESTERN AUSTRALIA

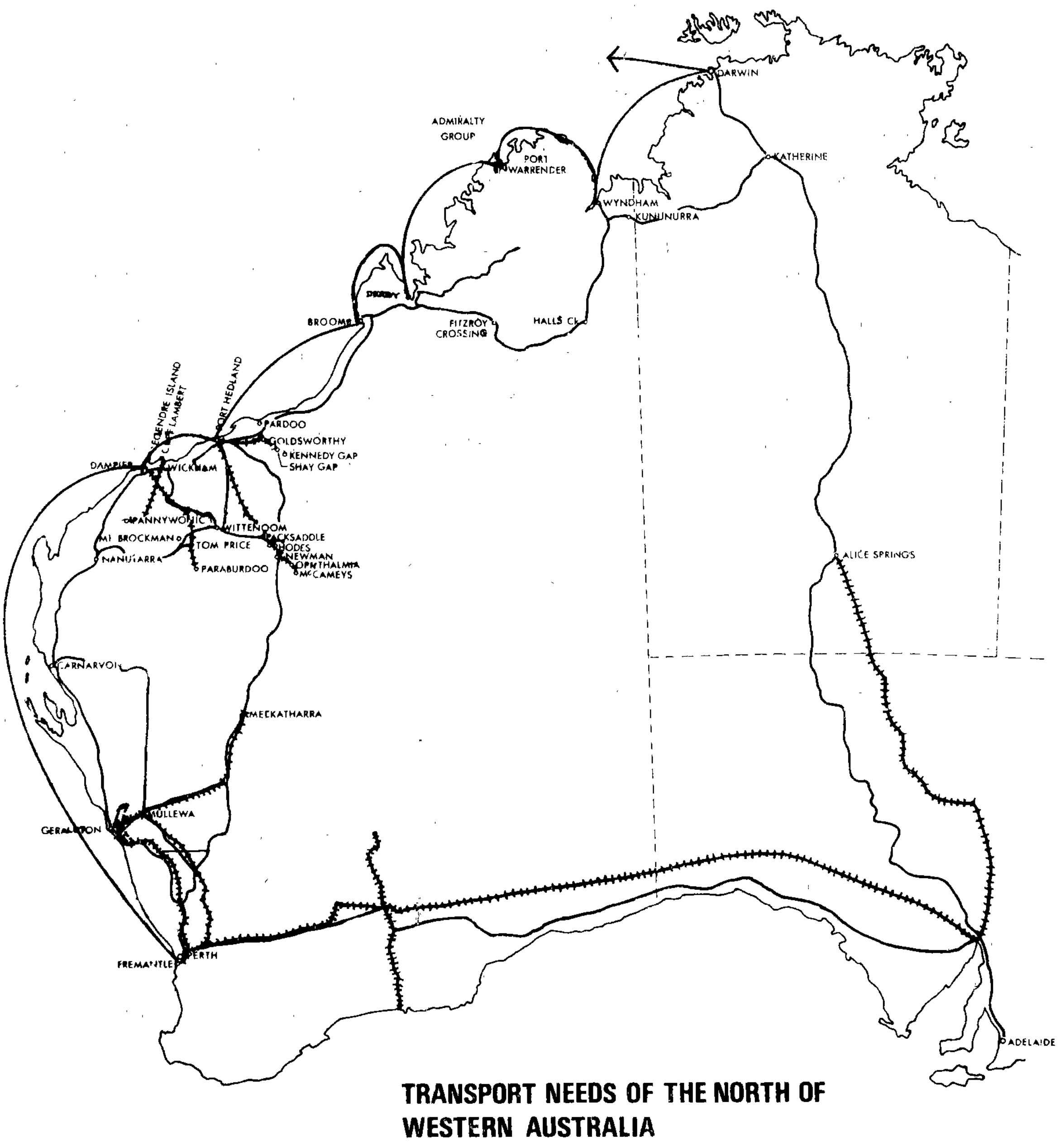


TABLE 1.3 - DISTRIBUTION OF FREIGHT ORIGINATING IN PERTH TO DESTINATIONS IN THE PILBARA, KIMBERLEY AND DARWIN REGIONS

Region of destination	Year	Tonnage					Percentage				
		State Shipping Service (a)	Direct road (b)	Rail/ road	Air (c)	Total all modes	State Shipping Service(a)	Direct road (b)	Rail/ road	Air (c)	Total
Pilbara	1968	75,400	43,000	38,000	1,400	157,800	47.8	27.2	(d)24.1	0.9	100
	1969	55,800	66,000	23,000	1,350	146,150	38.2	45.2	15.7	0.9	100
	1970	75,000	128,000	49,500	1,500	254,000	29.5	50.4	19.5	0.6	100
	1971	99,900	210,000	98,400	4,000	412,000	24.2	50.9	23.9	1.0	100
Pilbara, Kimberley, Darwin	1968	159,000	45,000	39,000	2,000	245,000	64.9	18.4	15.9	0.8	100
	1969	145,000	69,000	25,000	2,000	241,000	60.2	28.6	10.4	0.8	100
	1970	165,000	131,000	50,000	2,300	348,400	47.4	37.6	14.3	0.7	100
	1971	186,200	215,100	98,900	5,300	505,500	36.8	42.6	19.6	1.0	100

(a) Excludes some coastal cargo carried by other carriers. For instance, between June 1967 and September 1971 BHP ships (on 82 voyages) discharged 500,000 tons of cargo at Port Hedland.
(b) Includes tonnages by road direct from Perth under licence or permit. (c) MMA only. (d) Mt Newman facilities under construction. Extensive use made of rail/road.

Source: Director-General of Transport, Western Australia.

CHAPTER 2. TRANSPORT TO THE NORTH OF WESTERN AUSTRALIA

The area north of the 26th parallel makes up half of the area of Western Australia. It includes the whole of the Pilbara and Kimberley statistical divisions (one third of the area of Western Australia). Tables 2.1 and 2.2 show distances from Perth and Adelaide to various centres in the region.

2.1 THE REGIONS

The two significant regions in the north of Western Australia are the Kimberley and the Pilbara.

2.1.1 Kimberley

The Kimberley consists of portions of Fitzroy and North Kimberley and makes up an area of about 160,000 square miles.

In the Kimberley region, beef production is the major activity, with cattle movement by road to meatworks at Wyndham, Derby and Broome for export and interstate as livestock. Heavy production of grain sorghum and cotton on the Ord, Camballin and Dunham River irrigation schemes is forecast, but these products would also be exported. So, for the present study, movement of agricultural products out of the Kimberley is ignored.

Iron ore deposits are worked at Cockatoo and Koolan Islands in Yampi Sound. The ore is either exported or transported to Australian steel works by bulk carrier.

Exploration of offshore oil and gas fields has recently become a major activity on the coast. Some barytes (drilling mud) is moved from Wyndham to Darwin and Broome by State ships. Construction material is carried to Broome by road and by sea.

TABLE 2.1 - DISTANCES FROM PERTH TO SELECTED TOWNS AND LOCALITIES

(Statute miles)

Town	Road	Rail or rail/road	Sea	Air
Mullewa	291	339		
Geraldton	312	306	237	234
Meekatharra	475	608		400
Carnarvon	611		569	512
Mt Newman	736	875		636
Exmouth	835		792	715
Nullagine	846			742
Onslow	880		848	755
Wittenoom	904			692
Marble Bar	917			858
Dampier	1,005		991	788
Tom Price	1,014			650
Roebourne	1,020		1,036	810
Port Hedland	1,030	1,120	1,107	822
Goldsworthy	1,058			
Broome	1,368		1,374	1,045
Derby	1,470		1,568	1,130
Fitzroy Crossing	1,574			1,267
Halls Creek	1,773			1,401
Kununurra	1,995			1,481
Wyndham	2,007		2,007	1,456
Darwin	2,564		2,120	1,868

Sources: W A Main Roads Department
W A G R Annual Report 1971
W A Director-General of Transport

TABLE 2.2 - DISTANCES FROM ADELAIDE TO SELECTED TOWNS AND LOCALITIES

(Statute miles)

Town	Road		Rail
Alice Springs	1,055		979
Halls Creek	1,726)		
Kununurra	1,887)	via Tanami	
Wyndham	1,961)		
Darwin	2,001		
Kununurra	2,104)	via Katherine	
Wyndham	2,178)		

Source: W A Director-General of Transport

2.1.2 Pilbara

The Pilbara makes up an area of about 170,000 square miles. It has 400 miles of coastline and 150 miles of common border with the Northern Territory.

The major activity is the exploitation of high grade iron ore deposits which are distributed through the Hamersley Iron Province (some 20% by area of the region). On the basis of orders held in 1972, iron ore valued at $5,000m will be exported before the end of the study period. Development of ore handling and associated processing facilities to the end of 1972 amounted to about $1,500m. Export of iron ore is by bulk carrier and is not considered in the study.

Annex A outlines projected development in the Pilbara resulting from the discovery of substantial natural gas reserves. Backloading could be available when this development proceeds. This and related production data provided the basis for the population projections in Annex B.

The Pilbara is subject to cyclonic disturbances which can disrupt transport over a period of several weeks per year. Emergency stocks are held to carry over such incidents.

2.2 THE WEST AUSTRALIAN STATE SHIPPING SERVICE

WASSS is required to carry all cargo offered irrespective of nature, quantity or profitability, and to provide a liner service for perishable and other essential goods. The absence of backloading and the relatively low density of cargo offering have been important factors in the Service's inability to operate profitably.

The WA State Government looked to the introduction of LASH ships to put its operations on an acceptable footing. In April 1969 Commonwealth financial assistance was sought to re-equip the fleet with these vessels.

Tenders were called both in Australia and overseas for two LASH ships. The reason for calling tenders overseas was to see whether significantly lower price and suitable finance would be available for overseas building. While LASH ships had originally been estimated to cost about $5.5m each, the tenders from the Australian yards gave a price after subsidy of $9m to $9.5m each and the lower of the two overseas tenders received was for more than $12m.

Because of the high tender prices for LASH vessels the WA Government deferred the purchase in March 1971 and considered the acquisition of sufficient second-hand unit load ships to maintain a weekly service from Fremantle to Wyndham with possible extension to Darwin.

By the end of 1972, WASSS had imported, or was committed to importing, four second-hand unit load vessels of about 6,000 tons deadweight each, faster and better equipped than its existing mixed fleet. The timing and conditions of the imports are summarised in Table 2.3.

2.2.1 Share of Freight Traffic

For the Kimberley, sea has been the dominant mode with as much as 90% of the demand at the ports and 80% of the demand from the inland towns being satisfied by WASSS. Taking into account the encroachment of road transport, the BTE estimated that 80% of total freight to the Kimberley would be carried on WASSS vessels.

The WASSS share of freight to the Pilbara has varied considerably since the beginning of the major iron ore development and is treated as a variable in this study.

Historically, WASSS has carried a 25% share of all cargo entering the Darwin area of influence. Thus some of the cargo entering Darwin by sea may have been delivered as far south as Katherine. However, road transport has secured an increasing share of the cargo in the Darwin area of influence. The BTE estimated that WASSS could do no better than regain 25% of the freight to Darwin itself. In terms of all cargo entering the Darwin area of influence this would represent a reduction of the WASSS share of cargo from 25% to 21%.

TABLE 2.3 - WASSS FLEET RE-EQUIPMENT TIMING AND CONDITIONS

Ship	Details
'Wambiri'	Imported September 1971 Approval subject to - order for replacement building in Australia within 5 years of arrival - vessel to be re-exported when replacement ready for service.
'Beroona'	Imported October 1971 Approval subject to same conditions as above.
'Trans Michigan')	Approval to import granted August 1972.
)	
'Trans Ontario')	Approval on the understanding - imported vessels to be used for the purpose of evaluating the viability of the WASSS service - to be re-exported within 5 years unless replacements are orderd . if replacements are ordered consideration will be given to retention of the vessels for a further period.

NOTE: It is anticipated that the vessels 'Kangaroo' and 'Koolama' will be sold when the imported vessels 'Trans Michigan' and 'Trans Ontario' enter service in 1973.

2.3 LAND TRANSPORT SERVICES TO THE NORTH OF WESTERN AUSTRALIA

2.3.1 Rail Transport

In the Pilbara there are standard gauge railway lines of high capacity linking the mining towns to the ports. Some limited use of these lines is made by the mining companies for backloading from the ports to the mine towns. On the other hand, the narrow gauge lines from Perth to Geraldton and from Perth to Mullewa and Meekatharra have been used extensively (within their limited capacities) to shorten the road haul into the area. The railheads at Geraldton and Meekatharra have served as transhipment points for some 40% of all freight entering the Pilbara by land.

Current plans of the Western Australia Government Railways (WAGR), include the rerailing of certain sections of the Midland Railway between Perth and Geraldton and the Northern Railway between Perth and Mullewa. This work would be undertaken to cater for freight traffic which does not enter the study area. Moreover, some upgrading of the Mullewa to Meekatharra line will be necessary whether there will be traffic going north of the 26th parallel or not. This upgrading would permit increased train size and faster speed on a very old and worn track.

2.3.2 Road Transport

The road network of the area provides access to the ports, the mines and the railheads. To a lesser extent, the road system is also providing for private motorists and tourists. Sealing of the North West Coastal Highway is almost complete as far as Port Hedland. The Great Northern Highway from Meekatharra through Nullagine /Marble Bar, is expected to be sealed to Mt Newman by 1977. Other sections from Broome to Wyndham are already sealed to beef roads standards.

Various truck and trailer combinations and axle loads are now permitted on certain routes in the study area.

Regulations governing the transport of goods by road are policed by the WA Transport Commission.

There are certain situations in which road transport is the preferred mode:

- Some indivisible pieces of equipment cannot be transported by rail or sea because of their dimensions.
- Transshipment from rail or sea to road sometimes involves difficulties.
- There are weight limitations on some rail sections, e.g. Mullewa to Meekatharra.
- Urgency is occasionally an over-riding factor.

In these circumstances, the WA Transport Commission may grant permits for loads to be transported all the way by road.

An increasing percentage of intrastate freight has been forwarded to the Pilbara by the land modes. Explosives are now carried almost exclusively by land. We assumed that all explosives and at least 20% of all other freight throughout the Pilbara and Kimberley will always be forwarded by land transport. This sets the upper bound to sea-borne intrastate cargo to the Pilbara.

CHAPTER 3. STUDY METHOD

The problem was to identify transport systems that would minimise, or come close to minimising, the cost of transporting projected quantities of supplies and material from Perth and, to a limited extent, from Adelaide (via Central Australia), to a set of demand centres in the Pilbara and Kimberley and to Darwin. Thus, the transport task was considered as essentially logistic. However, within this task there are many possible combinations of sea, road, and rail.

Population and development projections by commodities (Annexes B, C and D) were translated into freight flows to major consumption centres, down to the level of individual mining town, or group of closely situated mining towns.

Choice between land and sea modes is affected by price, frequency of service, damage to freight and other factors, some intangible. It was realised early in the investigation that there was insufficient data available to develop continuous models of modal choice, so an approach restricted to resource costing of discrete steps in modal share was therefore adopted. Because of the number of possible alternative combinations, this approach was possible only by resort to massive use of digital computers.

Seven cases were considered:

- In Case 1, 20% of goods would be carried to the Pilbara by land and 80% by sea, 80% would be carried to the Kimberley by sea and 25% to Darwin by sea.

- Cases 2 to 5 ranged through increments of 10% in the land freight share to the Pilbara.

- Case 6 reduced the sea component to Pilbara to nothing but the Kimberley and Darwin shares remained at 80% and 25% respectively.

- Case 7 was restricted to land transport only.

3.1 LEAST RESOURCE COST CRITERION

The resource cost includes all the operating, maintenance, necessary renewal and directly allocable administration costs. Items such as road maintenance tax and port fees were ignored as merely financial transfers and not costs to the community. On the other hand, road and port maintenance costs were included. The resource costs spread over time were discounted at 7% and 10% to the base year and summed, giving a total present value resource cost. This was the criterion by which alternative transport systems were compared. 1972 was taken as the base year, to be consistent with costs which were calculated at 1972 values. The transport facilities north of Geraldton and Mullewa are predominantly used by Pilbara and Kimberley destined freight. The road and rail usage costs south of these locations were allocated on incremental bases provided by the Commonwealth Bureau of Roads and WAGR respectively. Ships do not call south of Dampier, other than to load in Perth, so their costs could be charged fully to the Pilbara, Kimberley and Darwin freights.

3.1.1 Other Modal Choice Factors

It would be extremely difficult to cost a number of factors that make one mode more or less attractive to a user than another, for example, frequency of service and damage in transit. Interviews with a wide range of users in the Pilbara and Kimberley indicated an equally wide range of judgments on such factors. While it may be possible to synthesise quantitative values for frequency, in terms of inventory costs, this would not necessarily conform with the user's valuation. It was therefore decided to ignore these factors initially, and to postulate that all transport systems providing a service frequency of weekly or better, would be of equal value. However, in Chapter 6-Evaluation of Results, the cost implications of longer door-to-door transit times and lower frequency of shipping are discussed in relation to those of land transport.

3.1.2 Pricing Policy

This report does not deal with the issue of pricing policy which would be essential to any application of the results. There would be two steps in putting the least cost system into effect. The first would be to provide the links and services indicated by the least cost solution. To some extent this would restrict the choices. The second step would be to adopt a set of freight rates that would lead users to assign their goods in the optimal way. This procedure would be feasible because rate setting on the publicly owned modes, together with road taxes, are available as policy instruments to secure the socially best system, i.e. the least resource cost system.

3.2 RESOURCE COSTS

3.2.1 Capital and Operating Costs

In the discounted cash flow calculations applied in this study, past or 'sunk' capital costs were ignored, even though the capital resources so acquired remain in use during the time frame of the study. Only new capital outlays were considered; for convenience, these capital outlays were assumed to occur at the beginning of the year concerned. In the case of assets jointly used, but which were created specifically for one type of traffic, e.g. ore railways, the entire capital cost was charged to that traffic. Only those additional costs attributable directly to other traffic were charged to it, e.g. rail terminal works and rail operating costs on mining company railways. Operating costs, which included not only items such as fuel and operators' wages but also repair and maintenance (e.g. periodic road resealing) were timed, again for computational convenience, at the end of the year concerned.

In determining present values, all costs were based on constant 1972 figures and were discounted to the beginning of that year.

3.2.2 Residual Value

Since many of the major capital investments had lives extending beyond the end of the study period, the residual value of such assets had to be determined. Residual value was taken to be the difference between the discounted capital streams corresponding to continued renewal into the indefinite future of existing assets as they wear out, and those corresponding to renewal of the assets in the first year after the termination of the study period, with subsequent continued renewal as they wear out. Thus, the residual value is the value of the remaining life of an asset at the end of the study period. Discount rates of 7% and 10% were used to obtain present values.

3.2.3 Depreciation

Because commercial vehicles (trucks) have relatively short lives compared with ships and railway rolling stock, it was convenient to take account of the capital costs of trucks through a conventional depreciation cost.

3.3 PROCEDURE FOR COMPUTATION

For each of the Pilbara/Kimberley sea transport tasks, minimum cost fleets of the four ship types in Annex E were derived by methods described in Annex F. This calculation included a timetable of ship procurement and discounted total sea transport costs. Cargo handling materials for the alternative ship types are determined in Annex G and costs associated with materials handling are in Annex H.

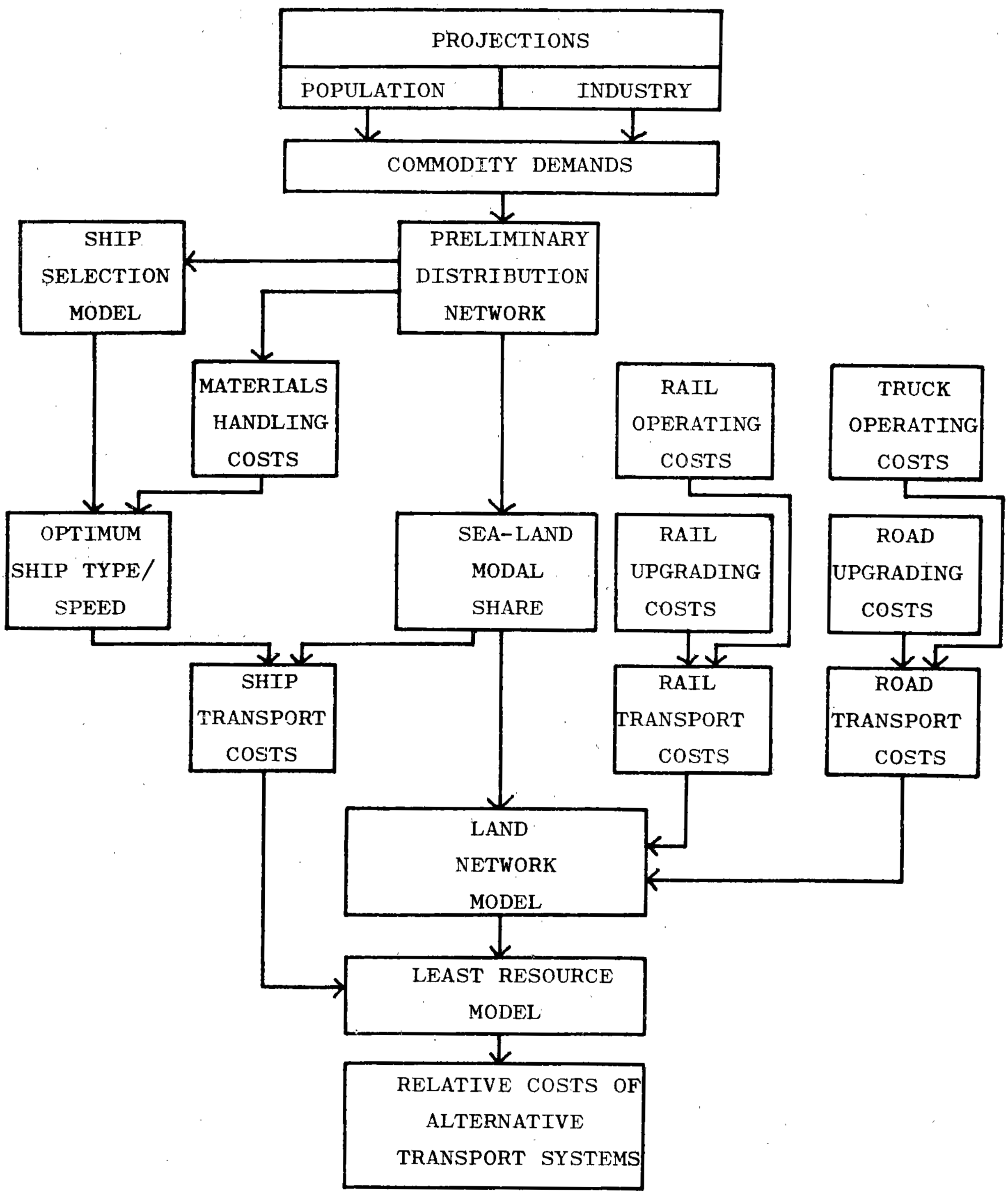
For land transport, the freight flows were allocated through the land network of road and railway lines in such a way as to minimise present value of the total cost. Present planned development of the road system is shown in Annex I to be adequate to meet the truck traffic projected during the time frame, even for an all-land system. Passenger car traffic was ignored. Corresponding investment strategies concerning railway development ranged from present WAGR plans, through further upgrading of the existing line to Meekatharra, up to construction of a new standard gauge line from Geraldton and Perth - see Annex J.

As explained in Annex K, the calculations leading to identification of a minimum cost land transport system utilised a bivalent integer linear programming technique, thus enabling many options to be evaluated over a range of forecasts and modal splits.

The minimum total transport cost for each option was then obtained simply by adding the costs of the complementary discrete modal shares of sea and land in the objective function of the bivalent integer linear programming model. For selected railway upgrading options and ranges of modal shares to sea and land, a matrix of near-minimal discounted total transport resource costs was obtained for each discount rate. Figure 3.1 illustrates the BTE approach to a least resource cost comparison of alternative transport systems. By programming this mathematical procedure for a computer, it was possible to examine a wide range of investment alternatives. In all, some 1,200 separate combinations of ships and rail/road alternatives were considered.

Furthermore, as the programs have been retained, it will be possible to re-examine quickly and accurately future alternatives as forecasts are updated and new alternatives present themselves. A probable application is an evaluation of transport alternatives associated with the proposed Pilbaraa Industrial Complex. This is particularly relevant if future development of the Pilbara arising out of the availability of offshore gas and mineral concentrates of the Murchison is to be studied in depth.

FIGURE 3.1 - BTE APPROACH: LEAST RESOURCE COST COMPARISON OF ALTERNATIVE TRANSPORT SYSTEMS



CHAPTER 4. COMMODITY PROJECTIONS

For projection purposes, north-west Australia was broken down into three demand areas, the Pilbara, the Kimberley and Darwin. The differing characteristics of each area and the quality of available data led to different approaches for the three demand areas.

4.1 PILBARA DEMAND AREA

The main projection was based on extracts from the 'Pilbara Regional Study' by Maunsell and Partners, dated May 1971. Further projections corresponding to enhanced development resulting from availability of North West Shelf gas were based on 'The Pilbara - A Development Concept' by the WA State Government Department of Development and Decentralisation, 1972 (summarised in Annex A). Maunsell used ore production and processing as the primary independent variable from which could be calculated the corresponding work force according to derived relationships, making assumptions concerning hours worked and labour efficiency. This figure, plus other adjustments, was then translated into a population figure according to projections of the proportion of married workers and of family size. Results are shown in Annex B. High and low projections were also made corresponding to retarded or accelerated development, in consultation with the WA Department of Development and Decentralisation. The production and processing projections are summarised in Table 4.1.

The projection of population for Dampier/Wickham associated with the Pilbara Industrial Complex was necessarily more approximate.

On the basis of these development and population projections, the corresponding freight requirements were broken down into categories. Explosives were included as a separate category because WASSS would not normally carry explosives in large quantities. Thus transport of explosives was restricted to the land modes; some direct import from overseas through the

TABLE 4.1 - PROJECTED FIVE-YEARLY IRON ORE PRODUCTION PATTERNS AT PILBARA MINES AND ASSOCIATED SECONDARY IRON ORE PROCESSING AT THE PILBARA PORTS

(Millions of tons per annum)

Mine town or port	Reduction in production below medium level for low projection				Medium projection of production levels				Increase in production above medium level for high projection			
	Year				Year				Year			
	1975	1980	1985	1990	1975	1980	1985	1990	1975	1980	1985	1990
IRON ORE PRODUCTION												
Mt Tom Price	0	0	0	0	25	25	30	35				
Paraburdoo	0	0	0	0	15	21	30	35				
Mt Brockman	0	0	0	5	0	0	0	5				
Koodaideri	0	14	11	0	0	14	25	25				
Mt Goldsworthy/ Shay/Kennedy Gap	0	0	0	0	8	8	8	8				
Packsaddle	0	5	0	5	0	5	5	10	NO CHANGE FROM MEDIUM PRODUCTIONS			
Mt Newman	0	0	0	0	33	33	35	40				
Ophthalmia	0	15	10	0	0	15	25	25				
Rhodes Ridge	0	5	0	0	0	5	5	5				
McCamey's	0	2	8	7	0	2	10	17				
Wittenoom	0	0	0	0	3	3	5	8				
Pannawonica	0	5	5	5	12	17	22	32				
SECONDARY PROCESSING PRODUCTION												
Dampier, Karratha, Legendre (Hamersley) Pellets + Agglomerates	0	5	4	2	6	11	15	18	0	8	9	11
Wickham, Cape Lambert (Robe River) Pellets + Agglomerates	0	2	4	3	5	7	11	16	0	0	0	2
Port Hedland (Newman/Goldsworthy) Pellets + Agglomerates	0	6	3	2	2	8	11	13	0	0	0	10

Source: WA Department of Development and Decentralisation.

Pilbara ports has occurred, but was ignored in the study. Because the bulk of fuel is carried in oil tankers to the ports and then distributed to the mines on company rail tankers, fuel oil was not considered as a category in the freight requirements.

Annex C and D document the bases of the assumed freight requirement factors for each of these categories, as follows :

- support of population : 2 tons per head per year
- housing and infrastructure construction : 50 tons per house constructed
- number of houses constructed: based on population increase, proportion married and family size
- plant maintenance, on the basis of ore production, in million tons of ore production per annum (MTPA):

  explosive at the mine - 800 tons per MTPA, each year
  maintenance at the mine - 300 tons per MTPA, each year
  maintenance at the port - 200 tons per MTPA, each year

- plant construction :

  port - 10,000 tons per MTPA, spread over five years
  mine - 5,000 tons per MTPA, spread over five years

Table 4.2 summarises the Pilbara freight tonnage requirements for all the principal towns and ports by the above categories.

TABLE 4.2 - PROJECTION OF FREIGHT DEMANDS BY COMMODITY RANGE FROM PILBARA MINE TOWNS: FIVE-YEARLY BASIS, MEDIUM RANGE

('000 tons)

Mine town	Year of projection																			
	1975					1980					1985					1990				
	Commodity range					Commodity range					Commodity range					Commodity range				
	L	M	E	C	H	L	M	E	C	H	L	M	E	C	H	L	M	E	C	H
Tom Price	6.2	7.5	20.0	0.0	0.9	6.2	7.5	20.0	5.0	0.0	7.2	9.0	24.0	5.0	0.6	8.0	10.5	28.0	5.0	0.5
Paraburdoo	4.1	4.5	12.0	6.0	14.0	5.5	6.3	16.8	9.0	0.8	7.2	9.0	24.0	5.0	1.1	8.0	10.5	28.0	5.0	0.5
Koodaideri	0.0	0.0	0.0	14.0	0.0	3.9	4.2	11.2	11.0	1.9	6.2	7.5	20.0	0.0	1.4	6.2	7.5	20.0	0.0	0.0
Goldsworthy	1.6	0.8	0.0	0.0	0.0	1.6	0.8	2.0	0.0	0.0	1.6	0.8	2.0	0.0	0.0	1.6	0.8	2.0	0.0	0.0
Shay Gap	2.1	1.6	4.4	0.0	0.0	2.1	1.6	4.4	0.0	0.0	2.1	1.6	4.4	0.0	0.0	2.1	1.6	4.4	0.0	0.0
Packsaddle	0.0	0.0	0.0	5.0	0.0	2.0	1.5	4.0	0.0	0.6	2.0	4.5	4.0	5.0	0.0	2.9	3.0	8.0	5.0	0.4
Mt Newman	7.6	9.9	26.4	0.0	2.7	7.6	9.9	26.4	2.0	0.0	9.0	10.5	28.0	5.0	0.3	8.8	12.0	32.0	5.0	0.5
Ophthalmia	0.0	0.0	0.0	15.0	0.0	4.1	4.5	12.0	10.0	2.0	6.2	7.5	20.0	0.0	1.3	6.2	7.5	20.0	0.0	0.0
Rhodes Ridge	0.0	0.0	0.0	5.0	0.0	2.0	1.5	4.0	0.0	0.6	2.0	1.5	4.0	0.0	0.0	2.0	1.5	4.0	0.0	0.0
McCamey's	0.0	0.0	0.0	2.0	0.0	1.5	0.6	1.6	8.0	0.4	2.9	3.0	8.0	7.0	0.6	4.6	4.6	13.6	7.0	0.9
Wittenoom	1.8	0.9	2.4	0.0	0.0	1.8	0.9	2.4	2.0	0.0	2.0	1.5	4.0	3.0	0.1	2.5	2.4	6.4	3.0	0.2
Pannawonica	3.4	3.6	9.6	0.0	0.0	4.6	5.1	13.6	2.0	0.6	5.6	6.6	17.6	8.0	0.6	7.5	9.6	22.5	9.0	1.2
Mt Brockman	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	2.0	1.5	4.0	5.0	0.6

NOTE: The letters L, M, E, C, H refer to ranges of commodities associated respectively with logistic support of the population, maintenance support of industry, explosives requirements at the mines, construction material during establishment or expansion of the mine, and housing construction.

4.2 KIMBERLEY DEMAND AREA

The population projections were based on the 'Report of Capital Expenditure Evaluation for the W A Coastal Shipping Commission' P A Management Consultants, 1970. The projections were updated as necessary by the Commonwealth Department of National Development. The factors used for support of population and housing/infrastructure construction tonnages were the same as those used for the Pilbara.

Table 4.3 summarises the freight tonnage requirements for the Kimberley.

4.3 DARWIN DEMAND AREA

Population projections for Darwin and its area of influence were obtained from the Department of the Interior (the relevant branch is now in the Department of the Northern Territory). Using the same approach as for the Pilbara, the population projections were translated into support and housing/infrasturcture tonnages (Annex C).

4.4 TOTAL TONNAGES

Using the above broad commodity classifications, annual requirements by commodity for the Pilbara, Kimberley, and Pilbara plus Kimberley are shown in Table 4.4 together with 25% of the Darwin requirements and the grand total tonnages used in the study. Exclusive of additional requirements arising from the Pilbara Industrial Complex, the study was concerned with the movement of some 426,000 tons in 1975, increasing to some 933,000 tons in 1990. The distribution of this freight by towns and by percentages of the grand total to each demand area is shown in Table 4.5.

TABLE 4.3 - PROJECTION OF FREIGHT DEMANDS BY COMMODITY RANGE FROM PORTS AND INLAND CENTRES[a] IN THE PILBARA AND KIMBERLEY AND IN THE DARWIN AREA OF INFLUENCE: FIVE-YEARLY BASIS, MEDIUM RANGE

('000 tons)

Port towns and inland centres	Year of projection																			
	1975					1980					1985					1990				
	Commodity range					Commodity range					Commodity range					Commodity range				
	L	M	E	C	H	L	M	E	C	H	L	M	E	C	H	L	M	E	C	H
Dampier	21.3	8.6	0.0	8.7	7.5	43.2	14.0	0.0	11.2	15.5	54.3	19.6	0.0	10.8	7.8	59.3	25.0	0.0	10.8	3.5
Wickham	13.1	2.4	0.0	2.2	7.9	18.9	3.6	0.0	7.6	4.1	25.0	7.4	0.0	9.2	4.3	33.5	12.0	0.0	9.2	6.0
Port Hedland	24.8	8.2	0.0	9.2	7.1	44.6	12.0	0.0	2.0	14.0	51.4	13.0	0.0	0.0	4.8	51.2	12.0	0.0	0.0	0.1
Broome	9.5	1.7	0.0	5.0	3.4	13.2	2.5	0.0	12.0	3.6	16.9	3.4	0.0	12.0	4.0	20.6	4.3	0.0	18.0	4.3
Yampi Sound	1.5	2.0	0.5	0.0	0.3	1.5	2.0	0.5	0.0	0.1	3.0	4.0	1.0	13.0	1.7	4.5	6.0	2.0	0.0	1.7
Derby	6.3	1.1	0.0	0.0	0.5	6.9	1.3	0.0	0.0	0.6	7.4	1.5	0.0	0.0	0.6	7.9	1.7	0.0	0.0	0.6
Admiralty Gulf	1.7	1.1	0.0	0.0	4.0	6.3	5.6	0.0	0.0	0.4	6.7	8.7	0.0	15.0	0.4	7.0	16.4	0.0	5.0	0.4
Wyndham	5.7	1.0	0.0	0.0	1.3	7.1	1.3	0.0	0.0	1.4	8.5	1.7	0.0	0.0	1.5	9.8	2.1	0.0	0.0	1.5
Darwin	119.7	21.2	0.0	0.0	81.1	186.5	35.3	0.0	0.0	109.1	272.0	54.7	0.0	0.0	146.2	378.4	80.5	0.0	0.0	181.7
Uranium Prov.	8.5	1.5	0.0	0.0	2.3	12.4	2.4	0.0	0.0	3.0	17.1	3.4	0.0	0.0	4.2	22.6	4.8	0.0	0.0	5.6
N T Rural	4.2	0.8	0.0	0.0	0.9	5.9	1.1	0.0	0.0	3.6	9.7	2.0	0.0	0.0	6.9	15.4	3.3	0.0	0.0	9.5
Aborigines	7.3	1.3	0.0	0.0	0.7	8.4	1.6	0.0	0.0	1.4	10.4	2.1	0.0	0.0	1.6	10.4	2.2	0.0	0.0	0.0
Katherine	18.1	3.2	0.0	0.0	1.6	19.9	3.8	0.0	0.0	1.9	21.9	4.4	0.0	0.0	2.2	24.0	5.1	0.0	0.0	2.5
Fitzroy-West Kim	7.3	1.3	0.0	0.0	0.7	8.8	1.7	0.0	0.0	3.6	12.7	2.6	0.0	0.0	3.5	14.3	3.0	0.0	0.0	0.0
East Kimberley	3.5	0.6	0.0	0.0	0.4	3.9	0.7	0.0	0.0	0.4	4.2	0.9	0.0	0.0	0.4	5.7	1.2	0.0	0.0	0.4
Halls Creek	4.4	0.8	0.0	0.0	0.3	4.9	0.9	0.0	0.0	0.3	5.3	1.0	0.0	0.0	0.3	5.7	1.2	0.0	0.0	0.4
Kununurra	5.3	1.8	0.0	0.0	6.1	11.1	4.2	0.0	0.0	6.5	16.9	6.8	0.0	0.0	7.0	22.7	9.6	0.0	0.0	7.2

(a) Excludes mine towns covered in Table 4.2.

NOTE: The letters L, M, E, C, H refer to ranges of commodities associated respectively with logistic support of the population, maintenance support of industry, explosives requirements at the mines, construction material during establishment or expansion of the mine, and housing construction.

TABLE 4.4 - PROJECTION OF FREIGHT DEMANDS BY COMMODITY RANGE FROM REGIONS IN THE PILBARA AND KIMBERLEY AND DARWIN: YEARLY BASIS, MEDIUM RANGE (a)

('000 tons)

Year	Regional grouping																Darwin (c)	Total freight (b)
	Pilbara Commodity range					Kimberley Commodity range					Pilbara plus Kimberley Commodity range							
	L	M	E	C	H	L	M	E	C	H	L	M	E	C	H	Total (b)		
1975	86.0	48.0	76.8	53.6	27.5	45.2	11.4	0.5	5.0	17.0	131.2	59.4	77.3	58.6	44.5	371.0	55.5	426.5
1976	102.2	50.4	77.8	44.1	83.2	47.9	12.2	0.5	6.4	13.5	150.1	62.6	78.3	50.5	96.7	438.2	60.4	498.6
1977	117.2	54.9	78.8	73.6	76.2	50.1	10.5	0.5	7.4	14.5	167.3	65.4	79.3	81.0	90.7	483.7	65.5	549.2
1978	130.8	60.3	79.8	77.9	69.4	53.0	13.3	0.5	9.4	15.3	183.8	73.6	80.3	87.3	84.7	509.7	70.9	580.6
1979	143.1	67.1	90.4	69.5	61.1	59.9	14.9	0.5	10.9	16.3	203.0	82.0	90.0	80.4	77.4	533.7	76.7	610.4
1980	152.0	74.0	118.4	69.8	40.5	63.7	20.2	0.5	12.4	16.9	215.7	94.2	118.9	82.2	57.4	568.4	82.7	651.1
1981	160.4	78.2	119.4	70.9	42.9	67.5	16.4	0.5	12.4	17.6	227.9	94.6	119.9	33.3	60.5	586.2	89.1	675.3
1982	167.0	83.8	120.5	74.0	37.9	70.8	23.6	0.5	13.5	18.2	237.8	107.4	121.0	87.5	56.1	609.8	95.9	705.7
1983	173.0	91.5	149.0	65.3	33.9	74.4	25.9	0.7	14.2	18.7	247.4	117.4	149.7	80.1	52.6	647.2	103.0	750.2
1984	179.4	98.0	154.5	69.5	28.6	78.2	28.2	0.9	14.8	19.1	257.6	126.2	155.4	84.4	47.7	671.3	110.4	781.7
1985	183.7	103.0	160.0	63.0	22.9	81.6	30.6	1.0	31.5	19.4	265.3	133.6	161.0	94.5	42.3	696.7	118.2	814.9
1986	188.5	107.1	166.0	63.0	24.4	85.4	35.0	5.2	34.3	21.8	273.9	142.1	171.2	97.3	46.2	730.7	126.4	857.1
1987	193 4	111.9	169.5	63.0	25.9	89.0	39.2	5.2	42.0	19.3	282.4	151.1	174.7	105.0	45.2	758.4	134.9	893.3
1988	198.4	114.9	182.4	63.0	26.9	92.7	42.5	5.8	27.0	20.7	391.1	157.4	188.2	90.0	47.6	774.3	143.8	918.1
1989	203.0	119.8	163.7	63.0	27.3	96.2	43.8	5.8	13.7	20.3	299.2	163.6	169.5	76.7	47.6	756.6	153.0	909.6
1990	206.4	122.5	167.7	63.0	14.4	99.1	46.8	5.0	28.0	17.1	305.5	169.3	173.7	91.0	31.5	771.0	162.2	933.2
Commodity totals	2,584.5	1,385.4	2,074.7	1,046.3	643.0	1,154.7	414.5	34.6	283.5	285.7	3,739.2	1,799.9	2,109.3	1,329.8	928.7	9,906.9		
REGIONAL TOTALS	Pilbara: 7,733.9					Kimberley: 2,173.0											Darwin: 1,648.6	11,555.5

(a) Also described as 'Realistic' and 'Mid-Range'. (b) Inwards freight only: all sea cargo from overseas and from Eastern States is excluded. (c) 25% only of the requirements for Darwin. The Darwin area of influence is not included.

NOTE: The letters L, M, E, C, H refer to ranges of commodities associated respectively with logistic support of the population, maintenance support of industry, explosives requirements at the mines, construction aterial during establishment or expansion of the mine and housing construction.

TABLE 4.5 - PROJECTION OF TOTAL INWARDS FREIGHT [(a)] DEMANDS FOR PORTS AND TOWNS EXPRESSED AS PERCENTAGES OF TOTAL REGIONAL DEMANDS FOR THE PERIOD 1975-1990, NOMINAL RANGE

Grouping	Total Demand '000 tons	% of Pilbara	% Kimberley	% of Pilb + Kimb	% of Pilb + Kimb + Dar (b)
Towns					
Dampier	1,403.3	18.1		14.2	12.1
Wickham	695.9	9.0		7.0	6.0
Pt Hedland	1,100.7	14.2		11.1	9.5
Tom Price	681.5	8.8		6.9	5.9
Paraburdoo	623.3	8.1		6.3	5.4
Koodaideri	473.0	6.1		4.8	4.1
Goldsworthy	70.4	0.9		0.7	0.6
Shay Gap	129.6	1.7		1.3	1.1
Packsaddle	191.7	2.5		1.9	1.7
Mt Newman	794.4	10.3		8.0	6.9
Ophthalmia	443.1	5.7		4.5	3.8
Rhodes Ridge	124.2	1.6		1.3	1.1
McCamey's	267.0	3.5		2.7	2.3
Wittenoom	143.6	1.9		1.4	1.2
Pannawonica	516.7	6.7		5.2	4.5
Mt Brockman	75.5	1.0		0.8	0.7
Broome	521.5		24.0	5.3	4.5
Derby	144.9		6.7	1.5	1.3
Yampi	151.2		7.0	1.5	1.3
Balance W. Kim (Fitzroy)	242.7		11.2	2.4	2.1
Wyndham	171.8		7.9	1.7	1.5
Kununurra	418.8		19.3	4.2	3.6
Admiralty Gulf	260.4		12.0	2.6	2.3
Balance E. Kim	84.5		3.9	0.9	0.7
Halls Creek	101.7		4.7	1.0	0.9
Regions					
Total Pilbara Towns	7,733.9	100.0	-	78.1	66.9
Total Kimberley Towns	2,173.0	-	100.0	21.9	18.8
Total Kimb + Pilb	9,906.9	-	-	100.0	85.7
TOTAL(Pilb + Kim + Dar)	11,555.5	-	-	-	100.0

(a) Excluding overseas and eastern states sea cargo. (b) 25% only of the requirements for Darwin. The Darwin area of influence is not included.

CHAPTER 5. FREIGHT DISTRIBUTION - ALTERNATIVES CONSIDERED

The demand centres identified separately in this study are schematically presented in Figure 5.1, in which are shown the transport links that exist at present or will exist when the associated projects commence. This network was the basis of the computer model.

5.1 SEA

Shipbuilding Division of the Department of Transport estimated ship construction costs for all types, container, roll on-roll off, unit load, and LASH, over a range of size and speed, using standard procedures (Annex E). They included an optimising procedure whereby the total cost of each type/size/speed combination was a minimum within port draught constraints, if applicable (Annex E).

For each modal split (Cases 1 to 6 described in Chapter 3), a fleet development programme for each type/size/speed combination over the study period was derived and the present values of the total shipping cost, including port and cargo handling costs, were calculated. This was done for both the 'bus stop' and the 'shuttle' schedules - see Figure 5.2. The analysis was done twice - first with some approximations to identify the most economical type/size/speed combination and second, a detailed analysis of ship procurement, scheduling and other factors for that combination.

The first analysis clearly identified the unit load type as economically preferred. The optimum size and speed were 6,000 tons deadweight (approx) and 14 knots respectively.

The second analysis was then performed in greater detail for the unit load type for both 'bus stop' and 'shuttle' schedules and for each modal split. 'Shuttle' schedules would be preferred for almost all years and modal shares. Table 5.1 shows the resulting fleet composition and ship usage pattern for each

FIGURE 5.1 - THE TRANSPORT NETWORK.

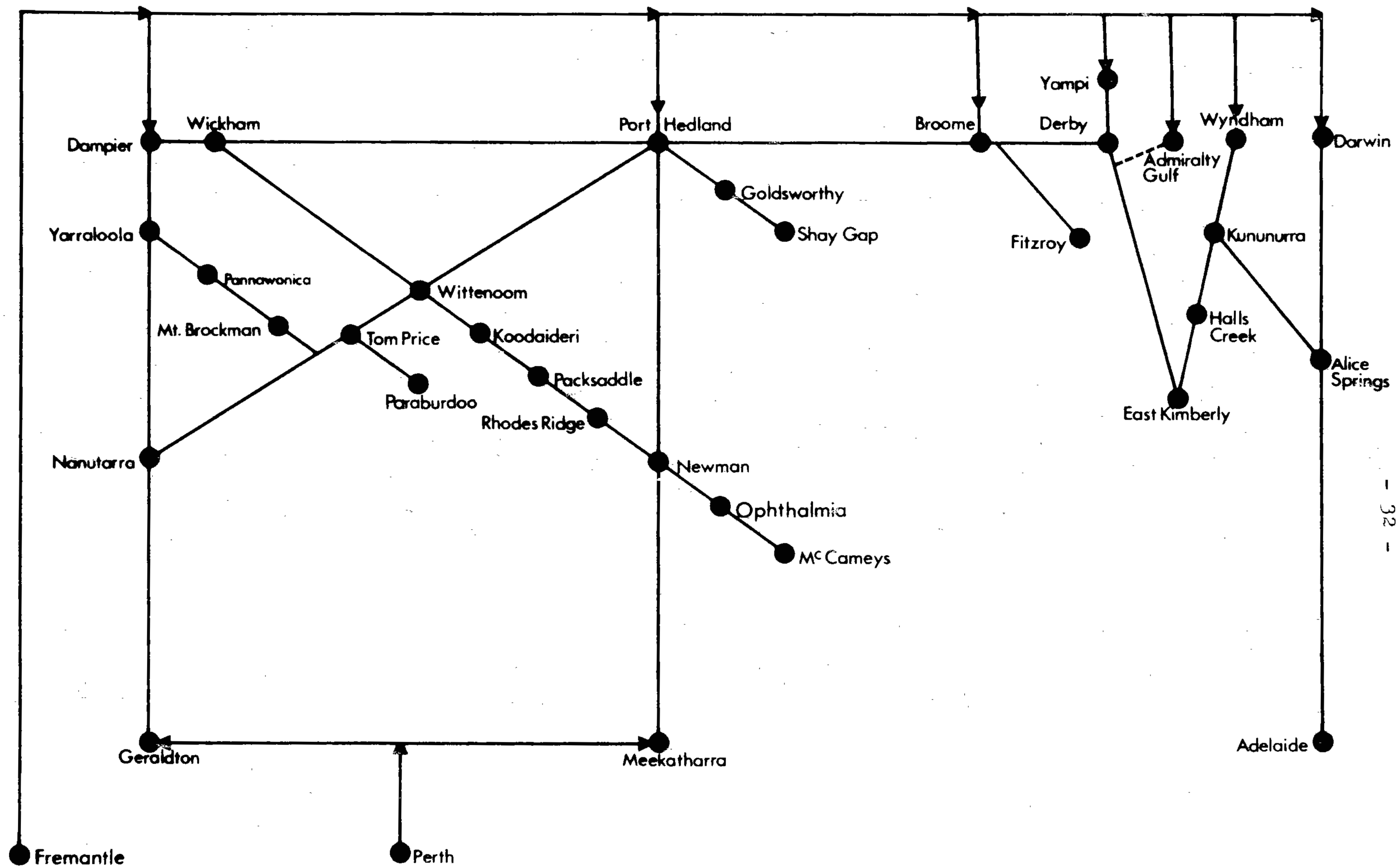


FIGURE 5.2 - WEST AUSTRALIAN STATE SHIPPING SERVICE: ROUTES OF THREE PROPOSED SERVICE PATTERNS (A, B, C) TO PORTS IN THE PILBARA AND DARWIN

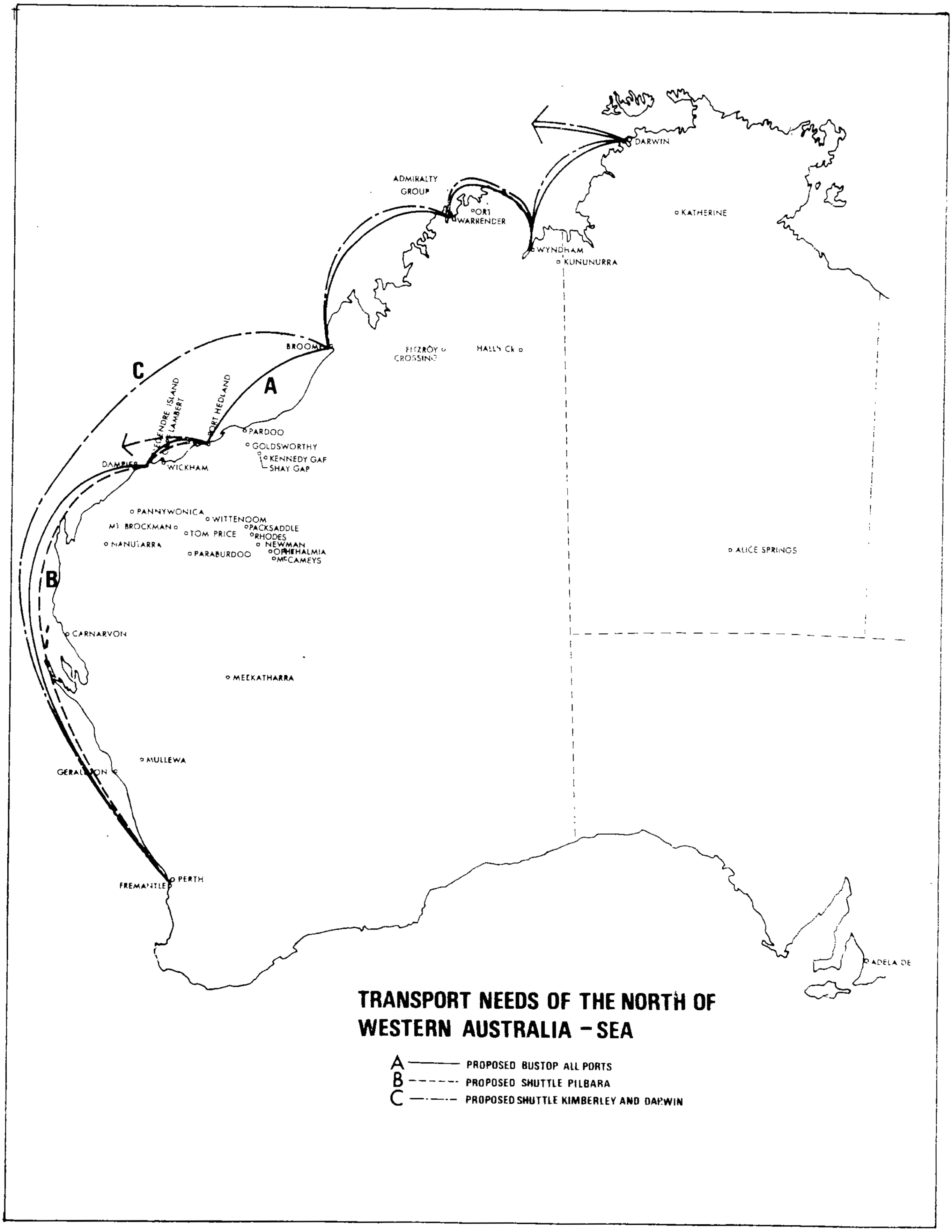


TABLE 5.1 - WEST AUSTRALIAN STATE SHIPPING SERVICE: PROJECTED FLEET TURNOVER, COMPOSITION AND TOTAL VESSELS TO ACHIEVE ALTERNATIVE SHARES OF THE PILBARA FREIGHT DEMAND AND FOR CONSTANT SEA SHARES TO KIMBERLEY (80%) AND DARWIN (25%)

(Number of vessels)

Specification for alternative shares to Pilbara freight demand	Fleet turnover and composition															
	Year 19 -															
	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
Case 1 (80% Pilbara)																
Vessel acquisitions	1	1		1	1	1	1			1						
Vessel sales				1	1	1	1									
Fleet composition																
- A	5															
- B		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
- C		3	3	3	3	3	3	3	3	4	4	4	4	4	4	4
Vessels in fleet	5	6	6	6	6	6	6	6	6	7	7	7	7	7	7	7
Case 2 (70% Pilbara)																
Vessel acquisitions	1		1	1	1	1	1			1						
Vessel sales				1	1	1	1									
Fleet composition																
- A	5	5														
- B			3	3	3	3	3	3	3	3	3	3	3	3	3	3
- C			3	3	3	3	3	3	3	4	4	4	4	4	4	4
Vessels in fleet	5	5	6	6	6	6	6	6	6	7	7	7	7	7	7	7
Case 3 (60% Pilbara)																
Vessel acquisitions	1		1	1	1	1	1			1						
Vessel sales				1	1	1	1									
Fleet composition																
- A	5	5														
- B			3	3	3	3	3	3	3	3	3	3	3	3	3	3
- C			3	3	3	3	3	3	3	4	4	4	4	4	4	4
Vessels in fleet	5	5	6	6	6	6	6	6	6	7	7	7	7	7	7	7
Case 4 (50% Pilbara)																
Vessel acquisitions		1		1	1	1	1			1						
Vessel sales				1	1	1	1									
Fleet composition																
- A	4															
- B		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
- C		3	3	3	3	3	3	3	3	4	4	4	4	4	4	4
Vessels in fleet	4	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6
Case 5 (40% Pilbara)																
Vessel acquisitions																
Vessel sales																
Fleet composition																
- A	4	4														
- B		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
- C			3	3	3	3	3	3	3	4	4	4	4	4	4	4
Vessels in fleet	4	4	5	5	5	5	5	5	5	6	6	6	6	6	6	6
Case 6 (0% Pilbara)																
Vessel acquisitions				1		1	1			1						
Vessel sales	1			1		1	1									
Fleet composition																
- C	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4
Vessels in fleet	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4

NOTE: Fleet composition gives the number of vessels employed in each of the voyage types A, B and C, where A is bustop all ports, B is shuttle to the Pilbara, and C is shuttle to the Kimberley and Darwin.

year in the project period. The cost profiles associated with these results are contained in Annex F. Methods and data used for estimating costs of cargo handling and port facilities are described in Annexes G and H. The results are presented in Annex H as total cargo handling and port costs per ton for all ports and ship types.

5.2 ROAD

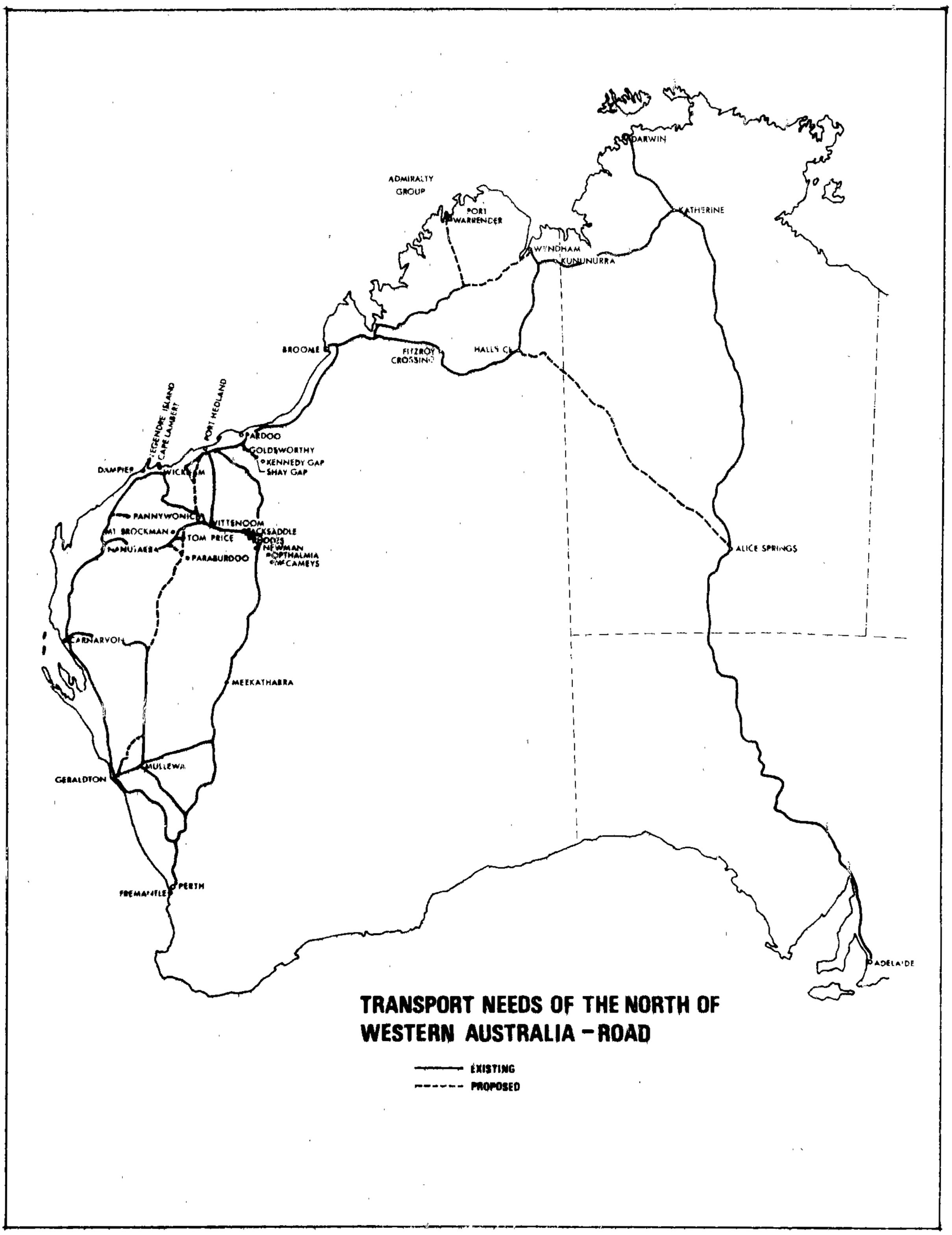
As shown in Annex I, the road upgrading evaluation procedure used by the WA Main Roads Department would only justify sealing the links Meekatharra-Mt Newman and Nanutarra-Port Hedland for the freight flows within the time frame of the study. Both of these improvements are planned for completion by 1977, so they were included in the present study as given. Taking into account projected tonnages, no other major road approaches this justification for sealing on freight flow grounds. Consequently, all other roads - see Figure 5.3 - are assumed to remain in their present state.

BTE accepted the WA Main Roads Department proposal that 'The Australian Roads Survey - 1969-74 - Specification', Commonwealth Bureau of Roads and The National Association of Australian State Road Authorities, 1971, be used as a source reference on maintenance cost functions for sealed and unsealed rural roads.

5.3 RAIL

The existing narrow gauge system from Perth to Meekatharra through Mullewa has restrictions on axle load, speed, and train length. However, WAGR has indicated that, despite low freight levels to stations en route, the BTE should assume that the Mullewa to Meekatharra line would remain open throughout the period 1975 to 1990 provided that, at the present freight level, upgrading is not necessary. On other sections there are existing WAGR plans for rerailing which would be implemented regardless of traffic moving north of the 26th parallel. These plans have been

FIGURE 5.3 - MAIN ROADS DEPARTMENT OF WESTERN AUSTRALIA: EXISTING ROUTES AND ROUTES PROPOSED FOR EXAMINATION IN THE STUDY TO SERVE THE PILBARA AND KIMBERLEY (a)



(a) Development of roads in the Northern Territory has not been considered in the study.

included in those cases which require continued use of the rerailed sections.

Five major rail alternatives were developed in conjunction with WAGR for comparison with other modes (see Table 5.2). To examine the effects of deferring the start of projects, all rail options were evaluated for four starting times with construction commencing in 1975, 1976, 1977 or 1978. These starting years are identified by the addition of a final numeral (1 to 4). Thus, A14 is the sub-option in which project A1 is commenced in year 4 (i.e. 1978).

The first alternative was the present WAGR plan for upgrading the Mullewa to Meekatharra line to permit higher axle loads, rerailing the Midland Railway and the Northern Railway lines as necessary, augmenting the rolling stock and improving the terminal works to permit movement of increased freight on the existing narrow gauge line. Two options were considered within this program, one to accommodate 250,000 net tons of freight and the other to accommodate 500,000 net tons (options A1 and A2). One sub-option, A14 would follow very closely the present planned timing.

The second alternative concentrates the upgrading measures on the the Midland Railway only. These upgradings would be more consistent than the A options with a new standard gauge line through Geraldton. Terminal works and rolling stock were also to be augmented to permit movement of 500,000 or 750,000 tons (options B1 and B2).

Rail options C and D were to upgrade the Midland or Northern Railways, as appropriate, to provide for 18.75 tons axle loads and to construct new standard gauge to Mt Newman from Meekatharra and Geraldton respectively. Rolling stock and terminal works were provided to permit carriage and handling of three annual tonnage levels. The latter would be constrained by terminal works and rolling stock rather than by track capacity.

TABLE 5.2 - PROPOSED RAIL ALTERNATIVES

Alternative	Description	Level	Net freight ('000 tons)			Axle loadings (tons)			Assumed split ('000 tons)	
			Midland	Northern	Total	Midland	Northern	Section	via Meekatharra	via Utakarra
								MULLEWA - MEEKATHARRA		
A	Existing pattern	1	145	105	250	16.0	16.0	18.75	105	
	(Upgrading Mullewa-Meekatharra)									
	(Rerailing Midland and Northern									
	as necessary	2	290	210	500	16.0	16.0	18.75	210	
B	Existing alignments and gauges							UTAKARRA - MEEKATHARRA		
	Upgrade Mullewa-Meekatharra									
	Midland	1	500	-	500	18.75	16.0	18.75	210	
	Utakarra-Mullewa									
		2	750	-	750	18.75	16.0	18.75	315	
C								MULLEWA - PORT HEDLAND		
	Existing alignment & gauges									
	plus new standard gauge line									
	Meekatharra to Newman	1	-	250	250	16.0	18.75	18.75		50
	Upgrading Mullewa-Meekatharra	2		500	500	16.0	18.75	18.75		75
	Goomalling-Mullewa									
	Gauge transfer at Meekatharra	3		750	750	16.0	18.75	18.75		100
D								UTAKARRA-PORT HEDLAND		
	Assumes Weld Range Railway									
	constructed by others and	1	250	-	250	18.75	16.0	18.75		50
	standard gauge connection									
	Weld Range to Newman	2	500	-	500	18.75	16.0	18.75		75
	Upgrading Midland									
	Closure Mullewa-Meekatharra	3	750	-	750	18.75	16.0	23.5		100
	Gauge transfer at Utakarra									
			MILLENDON-UTAKARRA					MILLENDON-PORT HEDLAND		
E	Assumes Weld Range railway									
	constructed by others and standard									
	gauge connection Weld-Range to									
	Newman	1	500	-	500			18.75		75
	New standard gauge railway									
	Millendon-Utakarra	2	750	-	750			18.75		100
	Closure Mullewa-Meekatharra									
	Moora-Millendon									

NOTE: Rail weight/yd in lbs = 4 x axle load in tons

Just as was done for options A and B, provision was made in C and D to defer construction for up to four years. New construction for D included completion of the new standard gauge line from Meekatharra to Mt Newman before starting on the new line from Geraldton to Meekatharra.

Agreements with the mining companies make provision for WAGR use of company standard gauge lines for hauling general freight. The companies themselves make use of the ore railways for haulage of freight and fuel from the ports. While only single track is available, there will be constraints on the number of freight trains per week. However, to meet present contracts, both Hamersley and Mt Newman railways must have double tracks by 1980. When the double track systems are complete there should be no traffic constraint on general freight trains.

By 1980 the Fortescue Valley link will be a single track serving Koodaideri. By 1990 all trunk routes from the mining towns to the ports are planned to be laid in double track and critical sections in triple track.

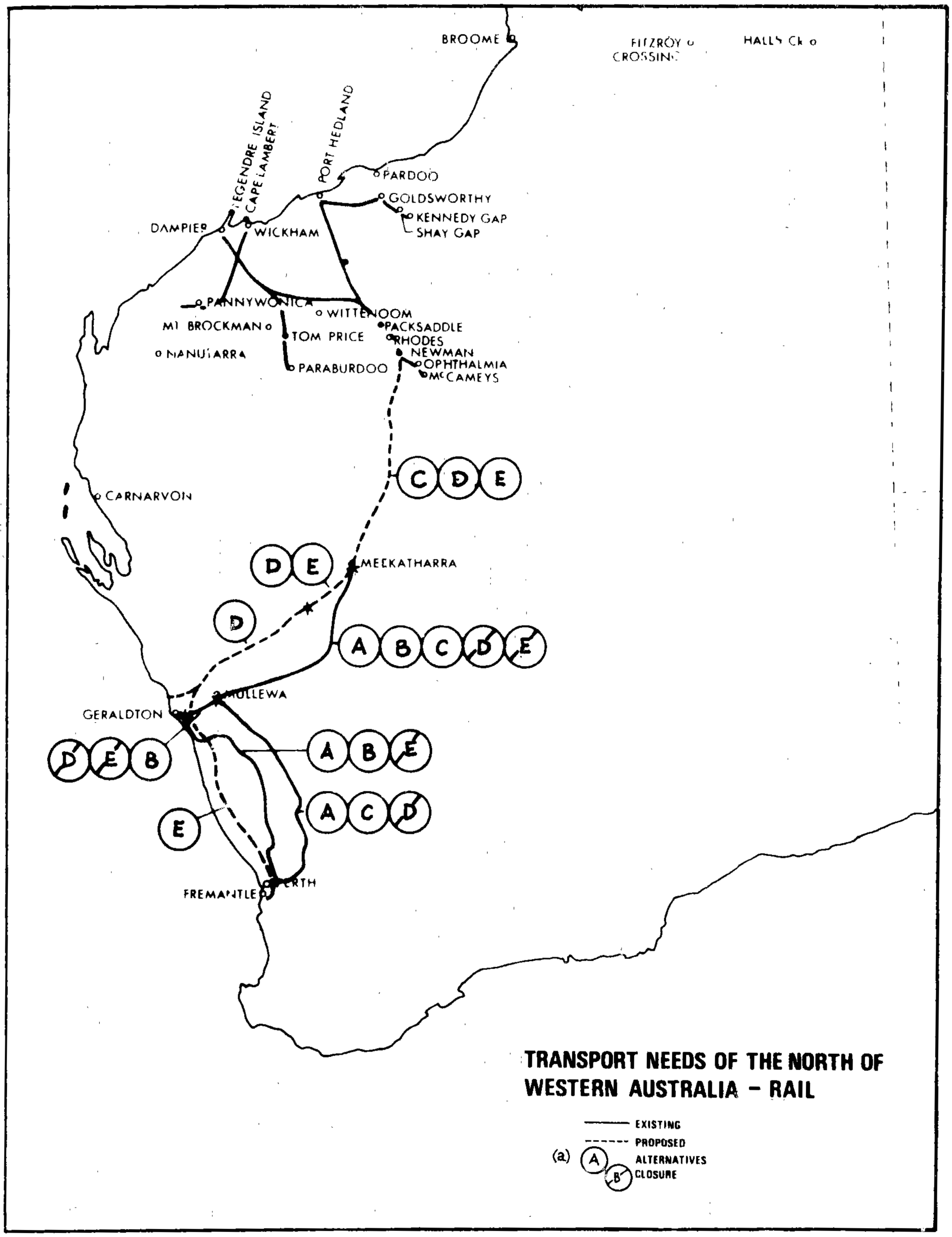
These projected developments are based upon Maunsell and Partners' Pilbara forecast and are summarised in Figure 5.4.

Examination of work schedules for rail construction indicates that, following an initial two year planning period, standard gauge links could be constructed in the following sequence:

Link	Construction period, years
Meekatharra - Mt Newman	3
Geraldton - Meekatharra	3
Perth - Geraldton	3

Operating costs for the D option were taken as equivalent to A option to Meekatharra until the Meekatharra-Mt Newman link was completed and then full option C costs until the Geraldton - Meekatharra link was finished. From the latter point

FIGURE 5.4 - WEST AUSTRALIAN GOVERNMENT RAILWAYS AND MINING COMPANY RAILWAYS: ROUTES OF FIVE PROPOSED RAIL DEVELOPMENT PATTERNS TO SERVE THE PILBARA



(a) The letters A,B,C,D,E indicate that the particular sections of line to which they are tagged are used for the rail option designated by that letter. A slash through the letter indicates the line section is closed for that option.

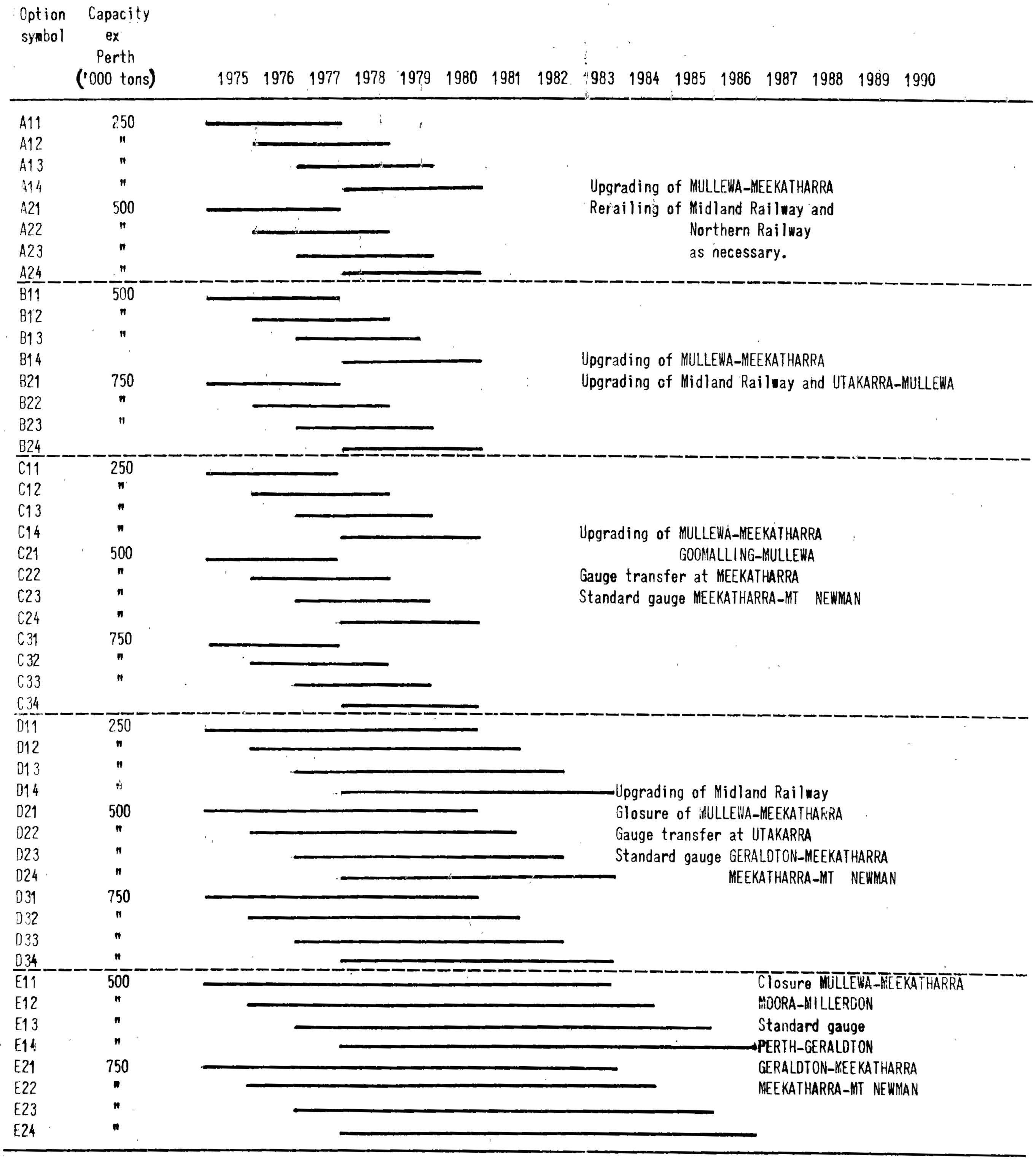
full D option operation costs were considered to apply for freight to Mt Newman and Pt Hedland/Dampier.

Similar assumptions were made for the E option to cover the phased building of a standard gauge line from Perth to Mt Newman over three consecutive periods of three years.

A summary of the proposed rail alternatives is provided in Table 5.2 while more detail on costs of the various rail options is in Annex J. Figure 5.5 illustrates how the rail options have been phased into the study.

The extra train services and transit times for the various rail options are at Table 5.3.

FIGURE 5.5 - WEST AUSTRALIAN GOVERNMENT RAILWAYS: A SUGGESTED CONSTRUCTION PATTERN FOR RAIL OPTIONS



NOTE: Prior to start of upgrading on construction projects the rail system is assumed to operate at costs equivalent to a 'do nothing' case with a capacity constraint of 160,000 tons p.a on freight for north of Geraldton and Meekatharra.

TABLE 5.3 - EXTRA TRAIN SERVICES AND TRANSIT TIMES FOR RAIL OPTIONS

	Rail terminal														
	Geraldton			Mullewa			Meekatharra			Mt Newman			Pt Hedland		
Rail option	Services per week	Gross train load	Transit time (ex Perth)	Services per week	Gross train load	Transit time (ex Perth)	Services per week	Gross train load	Transit time (ex Perth)	Services per week	Gross train load	Transit time (ex Perth)	Services per week	Gross train load	Transit time (ex Perth)
symbol	number	tons	hours	number	tons	hours	number	tons	hours	number	tons	hours	number	tons	hours
A 1	5	990	28	3	850	24	2	1120	36						
A 2	10	990	28	6	850	24	5	1120	36						
B 1	2	600	20	9	1500	24	5	1500	36						
	13	1070	20												
B 2	2	600	20	13	780	24	8	1150	36						
	21	1070	20												
C 1	-	-	-	8	1070	24	4	1500	36	3	3300	69	3	3300	78
C 2	3	1070	28	15	1070	24	10	1500	36	6	3300	69	6	3300	78
C 3	3	1070	28	22	1070	24	15	1500	36	6	6600	69	6	6600	78
D 1	2	600	20							6	1950	62	6	1950	71
	5	1070	20												
D 2	2	600	20							3	1950	62	3	1950	71
	14	1070	20							3	3300	62	3	3300	71
D 3	2	600	20							1	2460	62	1	2460	71
	21	1070	20							5	4920	62	5	4920	71
E 1	6	2080	20							6	2080	36	6	2080	45
E 2	6	4200	20							6	4200	36	6	4200	45

CHAPTER 6. EVALUATION OF RESULTS

6.1 SUMMARY OF METHOD

The criterion for comparing the alternative transport systems was present value of total resource cost. By separating the calculation of sea transport costs from those for land, it was possible to survey a range of sea/land modal shares in such a way that the most economic split could be identified.

On the basis of standard road usage criteria, it turned out that no major road upgrading was justified beyond that presently planned or being planned. Investment in land transport therefore centred on rail. The present capacitv of the rail links to the North West, the Midland Railway to Geraldton and the Northern Railway to Meekatharra via Mullewa, is 160,000 net tons per annum. Two upgrading levels considered were for throughputs of 250,000 and 500,000 tons p.a. Three other upgrading measures, with capacity up to 750,000 tons per annum were considered (see Table 5.2).

BTE produced low, medium and high freight forecasts, corresponding to retarded and accelerated mining and secondary production. However, the range of these forecasts was trivial by comparison with the range between the medium projection and that corresponding to the proposed Pilbara Industrial Complex, referred to here simply as the 'super-forecast'. The presentation of results is therefore restricted to the medium forecast and the 'super-forecast'.

It was clearly established that the optimum type of ship for the WASSS would be unit load, of 6,000 tons deadweight and 14 knots speed. As four present imported unit loaders will be in the WASSS fleet in 1975, it was clear that these ships will provide the least cost sea solution until re-export of the vessels becomes necessary. Expansion or contraction of the fleet depends upon cargo to be moved and this was taken into account in the programming of ship procurement. Similarly, rail options had interlocking aspects in permanent way construction and in rolling stock acquisition and replacement. Scheduling was also varied so that construction of each option could start in any year from 1975 to 1978.

6.2 RESULTS

Present values of the total costs discounted at 7% are shown in Table 6.1. The main deductions drawn from Table 6.1 are as follows:

(a) The total transport resource costs associated with lower capacity rail option A1 are insensitive to the degree of sea participation.

(b) The higher capacity rail upgrading (without new construciton) option B2, shows somewhat lower costs with no ship participation. This is because it is clearly more economic to utilise a given rail investment fully before introducing new ships.

(c) Total transport resource costs associated with closing the Meekatharra-Mt Newman gap by new standard gauge rail, option C, are not significantly higher than those associated with rail upgrading investments A and B. In fact, option C24 with no sea participation, a 500,000 ton per annum capacity line with construction starting in 1978 has a total cost within 1% of the combination of the best ship option, 80% by sea, concurrent with a minimum rail upgrading option, A14.

(d) The major standard gauge options, D and E, show total transport resource costs only slightly higher (3-10%), than the lower capital investment options.

TABLE 6.1 - PRESENT VALUE OF TOTAL TRANSPORT RESOURCE COSTS, DISCOUNTED AT 7%

($ million)

Rail option (a)	All land	Sea participation					
		Sea share of Kimberley traffic (held constant at 80%) plus sea share of Pilbara traffic at:					
		0%	40%	50%	60%	70%	80%
A01(b)	169	168	169	165	171	168	163
A11	165	166	168	164	171	168	164
A14	166	165	167	163	169	166	162
A21	162	163	168	166	173	171	167
B11	168	169	174	172	180	177	173
B14	166	166	170	167	175	nc	nc
B21	168	171	177	175	183	180	176
B24	165	167	172	169	177	174	170
C21	165	170	184	183	194	193	192
C22	164	168	181	180	nc	nc	nc
C23	168	170	181	180	nc	nc	nc
C24	163	166	177	175	184	nc	nc
C31	171	178	193	193	203	nc	nc
C32	169	175	nc	189	nc	nc	nc
C33	172	177	nc	187	nc	nc	nc
C34	167	171	nc	182	nc	nc	nc
D21	173	177	192	191	nc	nc	nc
D22	171	174	188	187	nc	nc	nc
D24	168	171	181	180	189	nc	nc
D31	175	182	198	198	208	nc	nc
E11	177	181	197	196	nc	nc	nc
E14	170	173	184	183	192	nc	nc
E21	183	190	206	206	217	nc	nc

(a) In each option code the initial letter refers to the rail option, the first numeral to a subdivision of the major option and the second numeral to the year in which work would commence (year 1 being 1975). The options are explained in Table 5.2. (b) As in A11, except that capacity is unchanged from present capacity of 160,000 tons p.a.

NOTE: nc = not calculated.

The present values of the capital components of these total costs are tabulated in Table 6.2. The table covers capital costs associated with ship procurement and with permanent way upgrading, construction and rolling stock for the specified capacity of the railway lines. The apparent discontinuity of the costs in traversing through a range of sea participation in the Pilbara arises from the 'lumpiness' of ship investment. This is due to the following increments in ship investment as sea participation is increased:

Pilbara sea share		0%	40%	50%	60%	70%	80%
Present value of ship investment attributable to Pilbara	$m	0.0	10.0	10.4	16.1	16.6	16.6

Thus, the increase in sea share from 60% to 80% can be accommodated with only a small increase in ship investment.

Table 6.2 gives an indication of the relative magnitude of investment as between predominantly ship options and major railway construction options, C, D and E. Generally, there would be little to choose between several of the lower cost sea and rail options in terms of either total cost (Table 6.1) or capital.

Table 6.3 presents the total transport resource cost (discounted at 7%) arising from the 'super-forecast' for a limited, but representative, range of options. These results indicate a clear advantage for the higher capacity C options over the A or B options (upgrading existing lines). Some of the major standard gauge options, D and E, also have lower costs. Reference to Table 6.1 shows that ship participation to the Pilbara at these higher levels of railway investment leads to higher costs. Thus ships to the Pilbara were omitted from the options considered in this preliminary examination of the 'super-forecast'.

TABLE 6.2 - PRESENT VALUE OF TOTAL PUBLIC CAPITAL INVESTMENT IN TRANSPORT FACILITIES, DISCOUNTED AT 7%

($ million)

Rail option (a)	All land	Sea participation: Sea share of Kimberley traffic (held constant at 80%) plus sea share of Pilbara traffic at: 0%	40%	50%	60%	70%	80%
A01(b)	7	21	31	32	37	38	38
A11	9	24	34	34	40	40	40
A14	6	21	31	31	37	37	37
A21	13	28	38	38	44	45	45
B11	19	34	44	44	50	51	51
B14	13	28	38	38	44	nc	nc
B21	22	37	47	47	53	54	54
B24	16	30	40	40	46	47	47
C21	43	58	68	68	74	75	75
C22	39	53	63	64	nc	nc	nc
C23	34	49	59	59	nc	nc	nc
C24	30	45	55	55	61	nc	nc
C31	54	68	78	78	84	nc	nc
C32	48	62	nc	73	nc	nc	nc
C33	42	57	nc	67	nc	nc	nc
C34	37	52	nc	62	nc	nc	nc
D21	52	67	77	77	nc	nc	nc
D22	46	61	71	71	nc	nc	nc
D24	36	50	60	61	66	nc	nc
D31	59	74	84	84	90	nc	nc
E11	60	74	84	85	nc	nc	nc
D14	40	54	64	65	70	nc	nc
D21	70	85	95	95	101	nc	nc

(a) In each option code the initial letter refers to the rail option, the first numeral to a subdivision of the major option and the second numeral to the year in which work would commence (year 1 being 1975). The options are explained in Table 5.2. (b) As in A11, except that capacity is unchanged from present capacity of 160,000 tons p.a.

NOTE: nc = not calculated

TABLE 6.3 - PRESENT VALUE OF TOTAL TRANSPORT RESOURCE COST ARISING FROM ENHANCED REQUIREMENT GENERATED BY PROPOSED PILBARA INDUSTRIAL COMPLEX, DISCOUNTED AT 7%

($ million)

Rail option (a)	All land	Sea participation
		Kimberley traffic only (held constant at 80%) (b)
A01 (c)	263	262
A11	259	259
A14	260	260
B14	258	259
B21	255	257
B24	255	256
C22	249	249
C23	255	255
C24	251	251
C31	237	236
C32	nc	239
C33	nc	249
C34	nc	243
D22	255	256
D23	261	261
D24	256	256
D31	240	241
E14	258	258
E21	246	248

(a) In each option code the initial letter refers to the rail option, the first numeral to a subdivision of the major option and the second numeral to the year in which work would commence (year 1 being 1975). The options are explained in Table 5.2. (b) No sea participation to Pilbara. (c) As in A11, except that capacity is unchanged from present capacity of 150,000 tons p.a.

NOTE: nc = not calculated

Furthermore, the evaluation model postulated a range of railway capacities up to 750,000 tons per annum, consistent with the maximum tonnages anticipated for the medium forecast. However, the Pilbara Industrial Complex proposals increase annual freight by 400,000 tons. The model, in keeping to the rail capacity constraint, allocates excess tonnage to road, at higher cost. However, the postulated rail capacities are well below the ultimate carrying capacity of the track. Thus, additional tonnages could be handled by merely acquiring additional rolling stock and terminal facilities. The costs shown in Table 6.3 are therefore overstated for the higher capacity rail options. Thus, differences between the 'all land' and 'ships to the Kimberley' cases are understated.

The analysis was repeated for a higher discount rate of 10%. The present value of total costs are shown in Tables 6.4 and 6.6, using the same nomenclature as before. The general comments relating to 7% discount apply here also. The corresponding present values of the capital investments are listed in Table 6.5. The relativity of the present values of ship and railway capital costs is little changed from those corresponding to the lower 7% discount rate.

6.3 CONCLUSIONS

A major finding of the study is that in terms of total community cost the construction of a standard gauge railway to the north west is a no more expensive way of meeting the transport needs of this region than using ships or land transport based on lower levels of railway development. One should be clear on what this means. First, it means that the higher capital outlays in building higher capacity standard gauge railway are almost exactly offset by the higher recurrent costs of ship and road transport.

Second, it means that, for virtually the same price, the community can have a major rail transport facility, providing good service and offering ample capacity for expanded needs. The merit of the standard gauge railway solution, if there is a substantial increase in the transport task, is readily seen in Tables 6.3 and 6.6 where standard gauge railway options C31 and D31 show up as the least cost ways of coping with the projected needs of a greatly expanded industrial complex in the Pilbara.

Other possibilities associated with the 'super-forecast' (but not dealt with) would be backloading of products such as caustic soda and ethylene dichloride to southern markets and forward loading of raw materials from the Murchison such as copper/zinc concentrates, nickel, yellow-cake and magnetite for processing at Dampier. These forward loadings could amount to more than 2 million tons per year and the backloadings to about 1 million tons per year.

However, the two options C and D still remain relatively favourable alternatives if the transport task to the Pilbara does not exceed the medium projections. Table 6.1 shows that, under these circumstances, options C31 and D31 are only 6% and 8% respectively higher in cost than the least cost alternative, at a discount rate of 7%. Furthermore, there is another Meekatharra-Mt Newman alternative, C24, which costs less than 1% more.

To some extent it is possible to further discriminate between these alternatives by a consideration of other costs and benefits. One has already been mentioned, capacity to perform a greater transport task. Others are associated with the fact that the study has been carried out on the assumption that there is a fixed transport task and that one way of performing this is as good as another. For instance, a daily service by road or rail and a weekly service by ship were assumed to be of equal merit. Thus, we have the following factors to consider:

- capacity for a greater transport task
- frequency of service
- door to door transit time.

An infrequent service entails higher inventory costs because merchants in the Pilbara would have to keep larger stocks if the service were weekly, for example, instead of daily. There is also an added benefit from the ability to obtain spare parts or replacements at short notice when there is a frequent service. Obviously sea transport would be less favourable in this respect, but there would be little or no difference between service by road and service by rail. In fact, only a little weight can be given to difference in service frequency for urgent consignments because there would be some road service to the Pilbara in any case.

It is a combination of higher door-to-door transit time and lower frequency that is unfavourable to sea transport. Average elapsed time by this mode to the Pilbara is estimated to be 7 days against 4 days by road or rail. Assuming a weekly service for sea and 2 day frequency for land, and an average value of $1,000 per ton for general cargo and an inventory carrying cost of, say, 15% p.a., leads to an increased present value cost of about $3 million over the study period, discounted at 7%, for a 50% sea modal share.

If one accepts that, on balance, a standard gauge link is the best choice, then a sea service to the Pilbara becomes redundant. Maintenance of shipping to the Kimberley is not so clear cut. For simplicity, the study assumed that stopping the service would lead to immediate sale of the present fleet for $4.5 million and instantaneous saving of the whole WASSS payroll. If these could not be attained in practice, retention of the service to the Kimberley would then be clearly justified.

Although a wide range of rail options has been covered in this report, other options exist which may be serious contenders, particularly if examined in conjunction with mineral prospects of adjacent areas. For example, a standard gauge extension from Leonora to Mt Keith (nickel) may create conditions which are more favourable to a further extension of the standard gauge to Mt Newman than to closing the Meekatharra - Mt Newman gap.

TABLE 6.4 - PRESENT VALUE OF TOTAL TRANSPORT RESOURCE COSTS, DISCOUNTED AT 10%

($ million)

Rail option (a)	All land	Sea participation					
		Sea share of Kimberley traffic (held constant at 80%) plus sea share of Pilbara traffic at:					
		0%	40%	50%	60%	70%	80%
A01(b)	130	132	134	131	137	134	130
A11	128	137	133	131	137	135	132
A14	126	129	131	128	135	132	129
B14	129	131	135	133	140	nc	nc
B21	133	137	143	142	149	147	144
B24	129	133	137	135	142	140	137
C22	134	139	150	150	nc	nc	nc
C23	135	140	149	148	nc	nc	nc
C24	131	135	144	143	151	nc	nc
C31	143	151	163	163	172	nc	nc
C32	140	147	nc	158	nc	nc	nc
C33	141	147	nc	155	nc	nc	nc
C34	135	141	nc	149	nc	nc	nc
D22	140	146	157	156	nc	nc	nc
D24	135	140	149	148	156	nc	nc
D31	147	155	168	168	177	nc	nc
E14	137	142	151	151	159	nc	nc
E21	155	163	176	176	186	nc	nc

(a) In each option code the initial letter refers to the rail option, the first numeral to a subdivision of the major option and the second numeral to the year in which work would commence (year 1 being 1975). The options are explained in Table 5.2. (b) As in A11, except that capacity is unchanged from present capacity of 160,000 tons p.a.

NOTE: nc = not calculated.

TABLE 6.5 - PRESENT VALUE OF TOTAL PUBLIC CAPITAL INVESTMENT IN TRANSPORT FACILITIES, DISCOUNTED AT 10%

($ million)

Rail option (a)	All land	Sea participation					
		Sea share of Kimberley traffic (held constant at 80%) plus sea share of Pilbara traffic at:					
		0%	40%	50%	60%	70%	80%
A01(b)	6	19	28	28	34	34	34
A11	8	21	30	31	36	37	37
A14	5	18	27	27	33	33	33
B14	12	25	34	34	40	nc	nc
B21	22	35	43	44	49	50	50
B24	14	27	36	36	42	42	42
C22	37	50	59	60	nc	nc	nc
C23	32	45	54	55	nc	nc	nc
C24	28	41	50	50	56	nc	nc
C31	53	65	74	75	80	nc	nc
C32	46	59	nc	68	nc	nc	nc
C33	40	53	nc	62	nc	nc	nc
C34	35	47	nc	57	nc	nc	nc
D22	44	57	66	67	nc	nc	nc
D24	33	46	55	55	61	nc	nc
D31	58	71	80	80	86	nc	nc
E14	36	49	58	59	64	nc	nc
E21	68	80	89	90	95	nc	nc

(a) In each option code the initial letter refers to the rail option, the first numeral to a subdivision of the major option and the second numeral to the year in which work would commence (year 1 being 1975). The options are explained in Table 5.2. (b) As in A11, except that capacity is unchanged from present capacity of 160,000 tons p.a.

NOTE: nc = not calculated

TABLE 6.6 - PRESENT VALUE OF TOTAL TRANSPORT RESOURCE COST ARISING FROM ENHANCED REQUIREMENT GENERATED BY PROPOSED PILBARA INDUSTRIAL COMPLEX, DISCOUNTED AT 10%

($ million)

Rail option (a)	All land	Sea participation Kimberley traffic only (held constant at 80%) (b)
A01(c)	204	206
A11	201	204
A14	200	203
B14	201	204
B21	201	205
B24	199	203
C22	200	204
C23	204	207
C24	200	203
C31	195	198
C32	nc	198
C33	nc	204
C34	nc	199
D22	207	210
D23	210	213
D24	204	207
D31	198	202
E14	207	210
E21	205	209

(a) In each option code the initial letter refers to the rail option, the first numeral to a subdivision of the major option and the second numeral to the year in which work would commence (year 1 being 1975). The options are explained in Table 5.2. (b) No sea participation to Pilbara. (c) As in A11, except that capacity is unchanged from present capacity of 160,000 tons p.a.

NOTE: nc = not calculated

ANNEX A

THE PILBARA DEVELOPMENT CONCEPT

The WA Government's proposal for the development of the Pilbara Industrial Complex gives rise to projected natural gas production and industries in the Dampier/Wickham area which are summarised in the following paragraphs.

A.1 NATURAL GAS

The lynch pin of the Complex is the North West Shelf natural gas. It would be used for :

- power generation
- process heat
- feedstock (ethane) for ethylene dichloride production.

Developers of North West Shelf gas have announced tentative plans to establish a 1,000 million cubic feet per day project. This would involve offshore production platforms, one or more undersea pipelines and an onshore processing plant to yield liquefied natural gas, liquefied ethane and condensate. The venture is expected to proceed regardless of whether the Pilbara Industrial Complex goes ahead.

Onshore gas sales to the Complex would require an increase in production, lifting daily throughput to about 1,600 million cubic feet. For a 25 year project life, total proven reserves would have to exceed 15 trillion cubic feet. There are very encouraging indications that economically recoverable reserves, considerably in excess of this level, will be established in the near future.

A.2 INDUSTRIES

A.2.1 Aluminium

To achieve low-cost power at the initial development stage it will be necessary to introduce a large, high load factor electricity user. An aluminium smelter is assumed to fill this role.

A.2.2 Steel

Both low-cost power and a stable work force earning wages comparable to those elsewhere in Australia are essential elements in the development concept. The aluminium smelter does much to bring about low-cost power but a viable new town development with a population exceeding 100,000 is required to achieve a stable work force.

To sustain a new town development of this magnitude a large employment base is required. A 'jumbo' steel plant would provide the greater part of this base.

A.2.3 Caustic Soda

The annual production of alumina in Australia is expected to be greater than 13 million tons by 1980, requiring for its processing more than a million tons of caustic soda annually. Virtually all of Australia's supplies are now imported. Bulk salt is already manufactured at Dampier by solar evaporation of sea water and caustic soda is obtained by electrolysis of salt, so the only requirement to make Australia self-sufficient in caustic soda is low-cost electricity.

A.2.4 Ethylene Dichloride

The two essential raw materials for ethylene dichloride manufacture will be available at the Complex, namely, co-product chlorine from caustic soda manufacture and by-product ethane from liquefied natural gas production. Ethane would be 'cracked' to form ethylene which would then be reacted with chlorine to produce ethylene dichloride (EDC), a basic requirement in the plastics industry.

A.2.5 Uranium Enrichment

World uranium enrichment capacity is now in surplus but a substantial shortfall is expected in the near future. This will require a massive investment to keep pace with the accelerated global demand anticipated during the 1980's. Low-cost power is usually the chief site choice criterion. The uranium 'yellow-cake' raw material for enrichment is available in Western Australia and in the Northern Territory.

A.2.6 Iron Ore Pellets

Natural gas is expected to benefit iron ore pellet producers because it is an ideal fuel for the indurating, or hardening, step. Roughly 1,000 cubic feet of gas would be required to indurate each ton of pellets. In addition, pelletising is a moderately heavy power user. Pellets are manufactured from fines or limonite and have an iron content of about 64% as shipped, thus raising the export value of the product. Metallised agglomerates result from another secondary processing of iron ore which yields material containing about 94% iron for feed in the electric furnace production of steel.

A.2.7 Special Alloy Steels (Ferro-Manganese)

Two additional concomitants of the steel industry are proposed for inclusion in the Complex. Manganese ore exports are planned from the Pilbara and extensive manganiferous iron ore exists in the Region. The availability of these ores coupled with low-cost power should enable competitively priced ferro-manganese to be produced and a 200,000 tons per year plant is assumed.

A.2.8 Service Industries

The Pilbara Industrial Complex would inevitably cause a wide variety of service industries to be set up in the Region. A few of the more noteworthy examples are:

- machine shops
- foundries
- refractory brick production
- carbon anode production
- process controls and instrumentation
- ship repair and servicing.

The steel industry alone would generate a great many supporting service industries in addition to those highlighted here.

ANNEX B

POPULATION PROJECTIONS

Population projections were required for the Pilbara, Kimberley, Darwin and the area of influence of the Darwin port. Primary sources for these projections were :

- 'Pilbara Regional Development Study' May 1971 by Maunsell and Partners Pty Ltd.
- 'Report on Development of Port and Harbour Facilities Darwin' January 1969 by the same consultants.
- 'Development of Capital Expenditure Evaluation for the WA Coastal Shipping Commission' 1970 by PA Management Consultants.
- 'The Pilbara - A Development Concept' Department of Development and Decentralization - WA 1972.

Substantial modifications were based on information provided by the Department of National Development, the Department of Interior and the WA Department of Development and Decentralization.

B.1 THE PILBARA

In making their Pilbara population projection, Maunsell and Partners assumed specific data and applied it to the port towns and to the mining towns. Basic factors included the hours worked, efficiency, the percentage of married workers and the number of temporary workers. For each port town assumptions were also made concerning the total ore handled per year as a result of ore production at the mines, and of production of pellets and metallised agglomerates, other primary workers, and a population adjustment. These assumptions were also modified by a delay of production in 1980 together with a corresponding shift in secondary processing. A further assumption was the doubling of the rate of the highly labour-intensive metallized agglomerates production at ports from 1980. The alternative production schedules corresponding to these assumptions are shown in Table 4.1 of the study.

Using these assumptions the BTE calculated, in the first instance, five year population projections on a low, medium, and high basis for centres in the Pilbara. These figures were also adjusted to examine the effect of long term development centred on Port Hedland or Dampier/ Wickham. In the event, the latter adjustment proved to have relatively minor effect and was subsequently dropped from the study. 'The Pilbara - A Development Concept', which favoured the Dampier area, introduced factors which were much more significant (see Annex A).

A paper on the application of Maunsell and Partners' methods to the changed assumptions was circulated to the Department of National Development and to the Department of Development and Decentralization WA. Following discussion on this paper, agreement was reached that the population projections in Table B.1 for the Pilbara would be a suitable basis for the study.

B.2 THE KIMBERLEY

We consulted with the WA Department of Development and Decentralization and agreed that population figures which they had provided to the PA Management Consultants for the years 1975 and 1985 for the Kimberley would serve as a basis for the BTE projection. To establish low, medium and high figures comparable to Pilbara projections it was agreed that the relationships between PA's total figures for optimistic, realistic and pessimistic would stand. Some minor changes were also incorporated. The adjusted projection as at July 1972 is

TABLE B.1 - PILBARA POPULATION PROJECTIONS

(Number)

Year	Projections					
	Low	Medium	Low	Medium	Low	Medium
	Dampier, Karratha, Legendre Island		Wickham, Cape Lambert		Port Hedland	
1975	10,650	10,650	6,550	6,550	12,400	12,400
1980	14,100	21,600	8,350	9,450	14,100	22,300
1985	22,050	27,150	11,150	12,500	21,300	25,700
1990	25,200	29,650	14,300	16,750	22,800	25,600
	Mt Tom Price		Paraburdoo		Koodaideri	
1975	3,100	3,100	2,050	2,050		
1980	3,100	3,100	2,750	2,750		1,950
1985	3,600	3,600	3,600	3,600	1,950	3,100
1990	4,000	4,000	4,000	4,000	3,100	3,100
	Goldsworthy		Shay Gap		Packsaddle	
1975	800	800	1,050	1,050		
1980	800	800	1,050	1,050		1,000
1985	800	800	1,050	1,050	1,000	1,000
1990	800	800	1,050	1,050	1,000	1,450
	Mt Newman		Ophthalmia		Rhodes Ridge	
1975	3,800	3,800				
1980	3,800	3,800		2,050		1,000
1985	4,000	4,000	2,100	3,100	1,000	1,000
1990	4,400	4,400	3,100	3,100	1,000	1,000
	McCamey's Monster		Wittenoom		Pannawonica	
1975			900	900	1,700	1,700
1980		750	900	900	1,700	2,300
1985	750	1,450	1,000	1,000	2,300	2,800
1990	1,450	2,300	1,250	1,250	3,300	3,750

NOTE: Mt Brockman projection is for a population of 1,000 persons in 1990 at the medium range.

shown in Table B.2, together with the scaling factors used to obtain low, nominal and high.

Subsequent discussion with the Department of Development and Decentralization in August 1972 confirmed that the Admiralty Gulf project should be deferred by ten years.

TABLE B.2 - KIMBERLEY POPULATION PROJECTIONS AND SCALING FACTORS

(Number)

Area	Projection 1975	Projection 1985
Yampi/Derby	3,000	5,500
Balance West Kimberley	4,400	6,000
Wyndham	2,700	4,000
Kununurra	2,500	8,000
Admiralty Gulf	3,000	3,300
Halls Creek	2,100	2,500
Balance East Kimberley	1,650	2,000
Total	22,900	37,300
	Scaling factors (a)	
- pessimistic (low)	0.796	0.711
- realistic (medium)	1.000	1.000
- optimistic (high)	1.489	1.957

(a) Based on PA totals.

B.3 DARWIN

In consultation with the Department of National Development and the Department of Interior we agreed to use projections as defined in the Maunsell Report with modifications provided by the Department of National Development. These modifications took into account the 1971 preliminary census figures for Darwin.

TABLE B.3 - DARWIN AND AREA OF INFLUENCE POPULATION PROJECTIONS

(Number)

Year	Darwin		Area of influence (a)
	Medium	Low	(b) Medium/Low
1975	58,900	54,300	18,030
1980	96,600	79,800	22,090
1985	145,300	111,900	27,500
1990	208,600	149,700	34,280

(a) Katherine, Uranium Province, Rural, Aborigines. (b) Medium and low projections coincide.

B.4 INTERPOLATION AND EXTRAPOLATION

From the above five-yearly projections, annual population projections for the Pilbara, Kimberley, Darwin and Darwin's area of influence were made for each of the intermediate years 1975 to 1990 by means of a four point Lagrange interpolation. Using these population figures, detailed forecasts of freight demands and, consequently, of freight distribution could be computed. These annual demands formed the basis of the subsequent evaluation of the options of both the land and the sea modes.

ANNEX C

POPULATION-BASED FREIGHT

C.1 HOUSING

In the whole of Western Australia, the average number of persons per dwelling is 3.52. Using occupancy figures from PA Management Consultants' report, 'Development of Capital Expenditure Evaluation for the WA Coastal Shipping Commission' 1970, the number of residents per house for various port and mining towns was derived. These are in Table C.1.

From the population growth per year for each centre (see Annex B), the number of houses required per year was calculated by difference methods.

The freight component of new houses was obtained from figures supplied by building contractors who had been engaged in major contracts in both the Pilbara and Kimberley. Inclusive of storm shutters, slab and structural changes necessary to withstand cyclones, and proportions of materials necessary for town development, the weights of material required are shown in Table C.2.

One experienced builder in the Kimberley area estimated that the freight for a four bedroom brick house in Kununurra, built to best metropolitan building standards, was about 60 tons. However, he stated that only 36 tons of materials go into a normal house in the Kimberley. In the Pilbara the building standards adopted by the mining companies are high and structural changes to withstand cyclones are necessary, so the BTE adopted 50 tons per house, inclusive of an allowance for community facilities. Use of this figure for the Kimberley could result in an overestimate in terms of present housing standards. However, the introduction of higher building standards in the Pilbara and Darwin may well result in a similar demand in the Kimberley, so 50 tons per house has been adopted to calculate the housing tonnages for all towns in Tables 5.3 and 5.4 of Chapter 5.

TABLE C.1 - PROJECTION OF AVERAGE NUMBER OF RESIDENTS PER HOUSE FOR CENTRES IN THE NORTH OF WESTERN AUSTRALIA

(Number)

Centre	Year			
	1975	1980	1985	1990
Dampier, Wickham, Kununurra	4.5	4.3	4.0	3.7
Port Hedland, Darwin	3.5	3.4	3.2	3.0
Broome	5.2	4.9	4.5	4.1
Derby, Yampi	4.7	4.5	4.2	4.1
Admiralty Gulf, Pannawonica, Mt Brockman	4.0	3.8	3.5	3.4
Tom Price, Paraburdoo, Goldsworthy, Shay Gap, Koodaideri, Packsaddle, Mt Newman, Ophthalmia, Rhodes Ridge, McCamey's	4.5	4.0	3.5	3.2
Wittenoom	5.5	5.0	4.5	3.7
Fitzroy Crossing, Wyndham, Other Kimberley	5.0	4.8	4.5	4.2
Halls Creek	8.0	7.0	6.0	5.0

TABLE C.2 - WEIGHT OF MATERIALS IN HOUSES AND ASSOCIATED SHARE OF COMMUNITY FACILITIES PER HOUSE

(Tons)

Component	House type	
	Steel frame	Timber frame
Common materials	13	13
Supply and fix items (a)	3	3
Frame	19	26
Slab	8	8
Community facilities	2	2
Storm fittings	1	1
TOTAL	46	53

(a) Prime cost items and air conditioning.

C.2 FURNITURE AND EFFECTS

Carriage of furniture is based upon volumetric loadings expressed at 40 cubic feet per cubic ton. An interstate furniture van would have a volume capacity of about 40 cubic tons or two complete households of furniture. However, the actual weight of furniture carried by the van would usually be less than six tons.

Mining companies usually supply furnished or partly furnished houses. Representative data in Table C.3 on furniture and on household goods which are moved with the average itinerant working family of two adults and two children were provided by the Department of Supply.

TABLE C.3 - WEIGHT OF FURNITURE AND EFFECTS OF AVERAGE WORKING FAMILY

(Tons)

Item	Weight
Robes and lounge suites	0.5
Refrigerator, washing machine, TV, mattresses	0.5
Tea chests of personal effects	0.5

Mining companies provided inventories of furniture which they supplied in company homes. Furniture life in the climate of the area was stated to be about 10 years. With labour turnover at less than twelve months for the initial phase of development of mining towns and assuming an average family of four the annual inwards movement of furniture and effects, exclusive of new furniture supplied in new company homes, is shown in Table C.4.

TABLE C.4 - FURNITURE AND EFFECTS REQUIRED ANNUALLY

(Tons)

Item	Weight per family	Weight per person
Furniture (replacement)	0.1	0.025
Effects	0.5	0.125
TOTAL	0.6	0.150

C.3 PERSONAL CONSUMPTION

Earlier studies of the logistic support for the north west have taken 5.3 to 5.6 tons per person as a basis for determining the freight requirements of the Pilbara. Unfortunately, the analysts have not defined either the commodity range or the units (weight or cubic). Because much of the subsequent study would depend upon it, BTE sought to establish a consumption figure. It was observed that, if the original estimate of 5.3 to 5.6 tons per capita is based on 40 cubic feet per ton and the actual density of logistic support is 100 cubic feet per ton, then the per person per annum consumption reduces to 2.1 to 2.2 tons weight.

BTE field work included a survey of retail outlets in the Pilbara and Kimberley, discussions with major suppliers of perishables, beverages and dry goods, and examination of manifests of some major freight forwarders. We also established that the average density of logistic support for the population was 100 cubic feet per ton and that domestic consumption including consumption of beverages varied from about one gallon per person per week to 2 gallons per person per week in the north west depending upon whether the area was settled or still in the construction phase. In the latter case the ratio of men to women was high.

Substituting these higher beverage consumption rates for those in the Bureau of Census and Statistics Estimated Quantity of Foodstuffs and Beverages for Consumption: Australia 1967-68, and allowing 20-25% by weight for packaging of food and groceries and 25% for beverages (Table C.5) and including furniture and effects from Table C.4, tha annual freight requirement per person became 1.04 to 1.33 tons weight. These figures bracketed the figure of 1.2 tons per person obtained by the BTE from analysis of freight manifests and population for mining towns.

In the report 'Development of Port and Harbour Facilities - Darwin' by Maunsell and Partners, 1969, the per person consumption of food, beverages and domestic general cargo including medicines was shown to be 1.22 tons per annum. The report also allowed a per person consumption of 0.275 tons of building materials and 0.5 tons of hardware per annum. The BTE accepted 0.775 tons per annum for household maintenance.

Accordingly, a figure of 2.0 tons per capita per annum was adopted for forecasting the logistic support of populations in the Pilbara, Kimberley and Darwin. Steel, machinery and motor vehicles forecast consumption ranged from 1.2 to 1.25 tons per capita per annum for the period 1975 - 1990. However, these figures were included in the Kimberley and Darwin forecast as maintenance tonnage for established industry.

C.4 POPULATION-BASED TONNAGES FOR PILBARA INDUSTRIAL COMPLEX

As only the start and finish estimates of population were available, we assumed a logistic S-shaped growth of population and from this an annual differential requirement for house construction. From the population projection and the housing requirement we derived an estimate of 350,000 tons freight required per year from intrastate sources.

TABLE C.5 - ANNUAL FREIGHT REQUIREMENT OF FOODSTUFFS AND BEVERAGES FOR NORTH WEST AUSTRALIA

(Pounds per person)

Commodity	Quantity	
Food and Groceries (a)		
Milk and milk products	56.9	
Meat (carcass equiv. weight)	217.4	
Poultry	24.2	
Eggs and egg products	27.9	
Fats and oils	31.2	
Sugar syrups	114.2	
Pulse and nuts	11.0	
Fruit (fresh fruit equiv.)	186.7	
Vegetables	262.9	
Grain products	190.0	
Tea	5.1	
Coffee	2.6	
Packaging	210.0	
Total food and groceries and packaging	1,340.1	
Beverages(b)	North West Australia	
	Settled	Developing
Wine, spirits and beer	520	1,040
Packaging	130	260
Total beverages and packaging	650	1,300
TOTAL FOOD, GROCERIES, BEVERAGES	1,990	2,640

Sources: (a) Official Year Book of the Commonwealth of Australia, 1969. (Estimated Quantity of Foodstuffs and Beverages Available for Consumption : Australia 1967-68)

(b) BTE survey of personal consumption of beverages in the Pilbara

ANNEX D

INDUSTRY-BASED FREIGHT

D.1 CONSTRUCTION REQUIREMENTS

Net of housing and logistic tonnages, the tonnage associated with the construction of mine and port facilities varies with the mine output, the extent of refining of ores at the port and the length of the interconnecting rail. The tonnage generated can be delivered direct from overseas to the port, direct from interstate ports, by intrastate shipping and by land. Mine output is expressed in millions of tons of ore per annum (MTPA).

Discussions with project officers at construction companies and supply officers with the mining companies indicated that about 60% of the freight for construction is delivered by land and intrastate shipping. It is this component only which is the concern of the study.

Further analysis of construction tonnage for several mines resulted in an estimate of 5,000 tons of construction per million tons of production per annum. While the construction period for a mine may spread over three years, the major deliveries from overseas usually take place within a period of about one year. Accordingly, we spread the remaining 60% of construction freight over the three year construction period. Also, in view of the uncertainty as to the actual start date for a sequence of new mine construction projects, we further assumed that the intrastate construction tonnage for each project should be spread over a five year period. Thus, while the aggregate over several years would be representative, in any one year our estimate may fall somewhat short of the intrastate peak for that year.

On the basis of the above assumptions, the intrastate component of construction freight requirement of 3,000 tons per

MTPA of ore was assumed and this was apportioned in the ratio of 2:1 between the port and mine giving :

Port: 2,000 tons per MTPA

Mine: 1,000 tons per MTPA.

D.2 EXPLOSIVES AND MAINTENANCE STORES

Mining companies confirmed that the annual consumption of ammonium nitrate was :

Mine: 800 tons per MTPA.

Maintenance records were made available and from these we assessed that the annual requirements for maintenance stores were at the rates of:

Port: 200 tons per MTPA

Mine: 300 tons per MTPA.

D.3 CONSTRUCTION TONNAGES: PILBARA INDUSTRIAL COMPLEX

At this early stage of the proposal it was not possible to obtain substantive estimates of the construction tonnage to develop the above industries at Dampier/Wickham. On the assumptions that each industry would absorb 150,000 tons of construction materials and that construction would proceed at a reasonably uniform rate throughout the period, we adopted a construction tonnage demand of 100,000 tons per annum for the area. Of this 50,000 tons was assumed to come from overseas sources.

ANNEX E

SHIPS FOR THE WEST AUSTRALIAN COASTAL TRADE

E.1 INTRODUCTION

This Annex is a summary of an investigation undertaken by the Shipbuilding Division of the Department of Transport of a variety of ship types, covering a range of sizes and speeds, to meet the future requirements of trading on the West Australian coast.

In order to determine the most effective type and size of ships which might be employed on the West Australian coastal trade, it has been necessary to develop special techniques to provide indicative cost estimates and outline technical data for a wide range of possible solutions.

The range of alternative proposals considered is set out in the following specification :

- Ship types:
  - unit load
  - container
  - roll on/roll off
  - LASH.
- Size range for each type:
  - 5,000 to 8,000 tons deadweight.
- Speed range for each type:
  - 16 to 22 knots.

E.1.1 Cargo Density

The stowage rate break-point in the present WASSS scale of changes at which cubic determines the charge is 40 cubic feet per ton. Most of the cargo has a stowage rate in the range 80-100 cubic feet per ton. A range of stowage rates was therefore examined. A rate of 80 cubic feet per ton was found to be the maximum possible, compatible with ship stability criteria.

E.1.2 Operating Schedule

The ships would be required to operate from Fremantle to the following ports :

- Dampier
- Port Hedland
- Broome
- Wyndham
- Darwin.

E.1.3 Dimensions

Standard naval architecture procedures provide for interdependence between the main parameters:

- length/beam ratio
- depth
- draught
- hull form.

The only restriction imposed was a draught restriction of 23 feet, dictated by harbour depths at Dampier and Wyndham.

E.1.4 Range

The proposals developed allow for a round trip, Fremantle -Darwin - Fremantle. Assessment of oil fuel has been made on this basis, with due allowances for 'in port' operations. It has been assumed that fresh water distillers will be fitted, and only limited fresh water capacity is, therefore, provided.

E.1.5 Cargo Gear

All proposals incorporate what has been assessed to be an adequate and comprehensive range of cargo handling equipment to facilitate rapid handling of cargo and turn-round in ports. No allowance has been made for handling cargo by shore facilities.

E.1.6 Machinery and Auxiliaries

For the current investigation the main machinery installation has been based on the use of medium-speed diesels throughout. Single screw propulsion has been assumed for all ship types, except the roll on/roll off for which, due to the nature of their operations, twin-screw machinery is considered more feasible.

Adequate electrical generating plant is provided, also bow thrusters to facilitate manoeuvring in port, for all alternatives.

E.1.7 Technical

The investigation made allowances for preliminary consideration of all main technical aspects, such as freeboard, weight estimation, cubic capacity and stability.

E.1.8 Manning

The manning for each alternative has been assessed on current practices operating on the Australian coast. Allowance has been made for such aspects as unmanned engine room, automation of cargo gear and mooring equipment.

E.1.9 Gross Tonnage

On the basis that this is intended to provide a comparative measure of size, the gross tonnage figures have been assessed on a uniform basis, essentially related to the enclosed cubic capacity of the various proposals.

E.2 GENERAL APPROACH

For each of the specified ship types enumerated in section E.1, a computer program was developed such that an estimate of the construction cost and of those operating costs directly related to the ship could be provided. The computer programme provided for the following essential alternatives for each ship type :

- cargo weight
- cargo stowage rate
- service speed.

The basic technique employed was based on that developed by Fisher and Benford, related to computer-aided ship design. Some of their relationships had to be revised to take account of recent Australian shipbuilding experience.

Construction cost estimates were based on information available for ships recently built or at present being built in Australian shipyards.

Operating cost estimates were based on data supplied by the West Australian State Shipping Service and the Australian National Line.

The next four sections summarise the main results of the analyses of the four ship types.

E.3 UNIT LOAD SHIPS

These can be described as modern, general purpose vessels, with special consideration being given to the provision of large hatchways and comprehensive range of cargo handling gear (cranes) to facilitate loading and discharge of cargo.

Their advantage lies in their ability to handle a wide range of cargoes, including packaged, palletised or containerised forms, but not restricted to these. The ships can also, by operation of two or more cranes in unison, handle larger units such as ISO containers. This provides for a wide range in size of units which can be readily handled.

Disadvantages include less rapid turn-round in port as compared with other ship types, also additional labour in stowage of cargoes and the additional upkeep of a larger number of items of cargo handling gear.

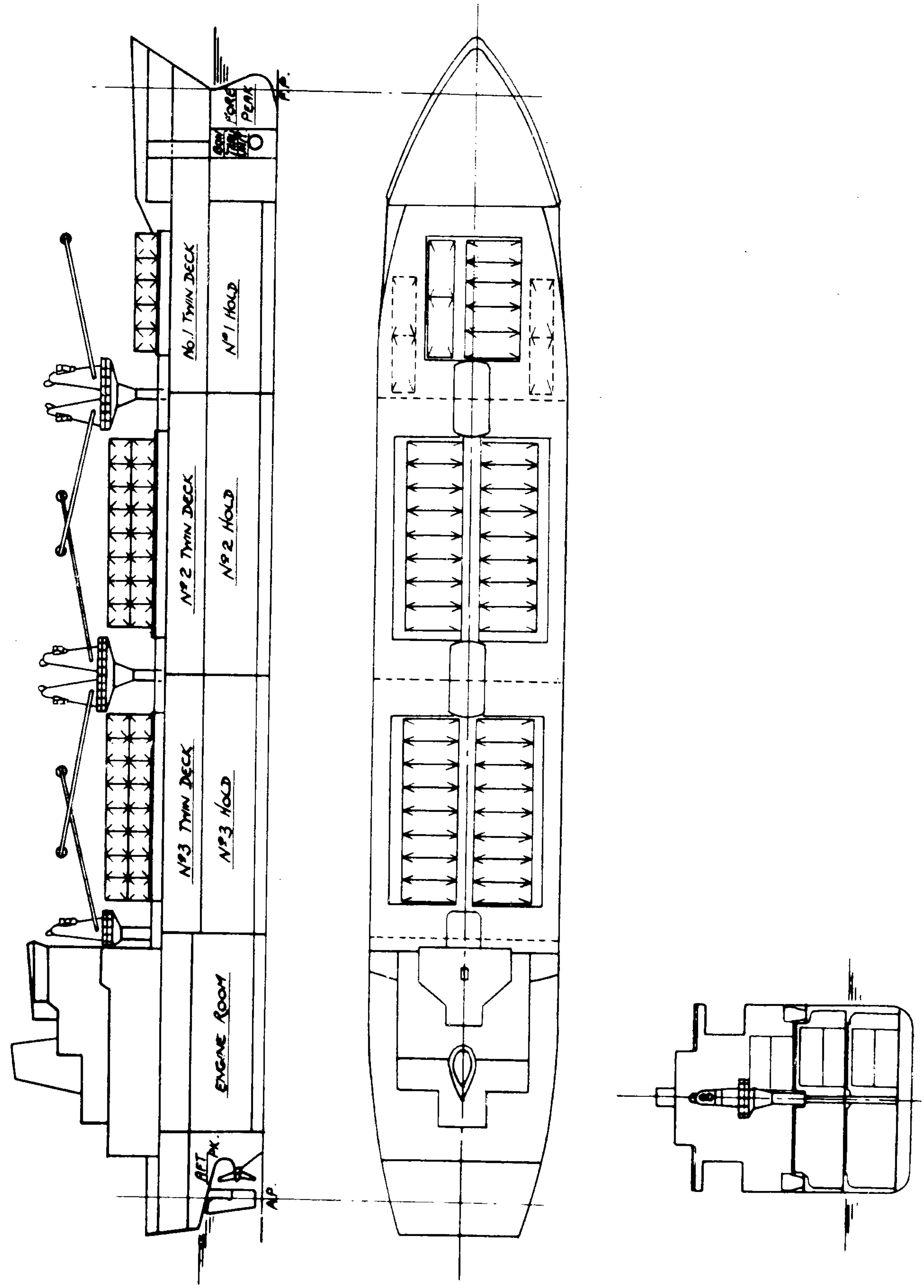
Table E.1 summarises the principal characteristics and indicative costs of alternative sizes of unit load ships, and Figure E.1 illustrates a typical layout of the type of vessel considered.

TABLE E.1 - UNIT LOAD SHIPS - SINGLE SCREW DIESEL

		Cargo weight (tons)								
		4920			6396			7872		
		Service speed (knots)			Service speed (knots)			Service speed (knots)		
		14	17	20	14	17	20	14	17	20
Dimensions										
- length (BP)	ft	327	360	376	353	386	425	376	409	441
- breadth, MLD	ft	58	62	65	62	65	65	65	69	72
- depth, MLD	ft	31	33	36	34	36	36	36	39	41
- draught	ft	19	21	23	20	22	23	21	23	23
Cargo										
- stowage rate	cu.ft/ton	80	80	80	80	80	80	80	80	80
- no. of $12\frac{1}{2}$ ton cranes		4	4	4	5	5	5	5	5	5
Power	hp	4,960	9,000	15,010	5,490	10,050	16,480	6,160	10,990	18,360
Fuel Rates										
- main engine	tons/day	16.7	29.5	49.2	18.7	32.5	54.1	20.7	36.4	60.0
- auxiliaries (a) (at sea)	tons/day	3.8	4.3	4.9	3.9	4.4	5.1	4.0	4.5	5.3
(in port)	tons/day	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Gross tonnage		5,904	5,904	5,904	7,380	7,380	7,380	8,856	8,856	8,856
Construction cost (variable as at end of 1972)	\$m	6.6	7.4	8.4	7.2	8.2	9.6	7.9	8.8	10.3
Complement		30	31	32	30	31	32	31	32	33

(a) Auxiliaries consumption rates above are on basis of independent alternators (i.e. no engine driven alternators) and include an allowance for carriage of about 100 - 20 ft ISO refrig. containers. This is equivalent to auxiliaries consumptions of about 1 ton/day at sea and 3 tons/day in port.

FIGURE E.1
UNIT LOAD SHIP
TYPICAL LAYOUT



E.4 CONTAINER SHIPS

A cellular container ship is designed essentially for the special purpose of carrying cargo prepacked in containers of uniform dimensions. In the current design study the ISO 20ft x 8ft x 8ft size of container has been taken as the modular unit. For structural and hydrodynamic reasons, the best cargo utilisation is achieved at or about amidships, and decreases at both ends of the ship. For this reason, No. 1 hold at the fore end of the ship is not suitable for stowage of containers and is therefore available for carriage of a limited amount of general cargo. To facilitate rapid loading and discharge of container cargoes, the design provides for two gantry cranes of about 22 tons lifting capacity. The forward crane is provided with an overhead travelling crane of up to 10 tons capacity to handle general cargoes in No. 1 hold.

The principal advantage of the cellular container ship is its ability to rapidly handle a restricted number of uniform container units, leading to fast turn-round times in port. To ensure best utilisation of such ships it is necessary to obtain the best possible stowage of container units and also to provide rapid transportation facilities ashore. An additional advantage is, of course, the reduced personnel required for cargo handling operations as far as the ship is concerned.

The main disadvantages are the restriction in cargo unit to essentially one size and the increased first cost of ship (including provision of containers).

Table E.2 summarises the principal characteristics and indicative costs of alternative sizes of cellular container ships, and Figure E.2 illustrates a typical layout of the type of vessel considered.

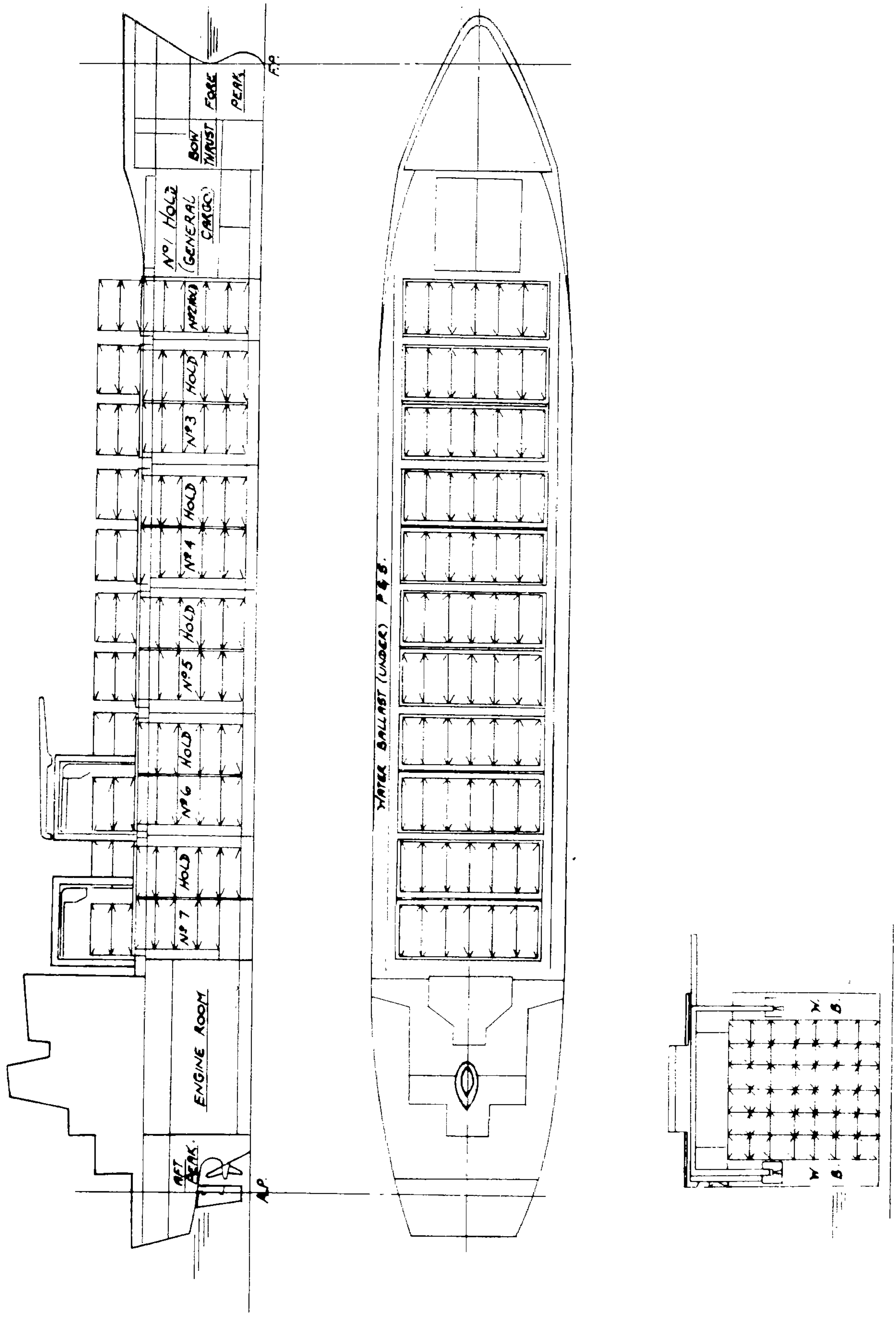
Although the ship type described above had some capacity for non-containerised cargo (in No. 1 hold - Figure E.2), it transpired that this would be insufficient for the estimated amount of this cargo over the time frame of the study (Annex H). A 'hybrid' container ship was therefore postulated having the same general characteristics as the cellular container ships specified in Table E.2 except that about one-third of the cargo capacity would be available for general cargo and that additional cranes would be provided to handle this cargo. It was assumed that these changes would result in an additional construction cost of $0.2 million per ship.

TABLE E.2 - CELLULAR CONTAINER SHIPS - SINGLE SCREW DIESEL

		Cargo weight (tons)								
		4920			6396			7872		
		Service speed (knots)			Service speed (knots)			Service speed (knots)		
		14	17	20	14	17	20	14	17	20
Dimensions										
- length (BP)	ft	425	438	454	441	458	477	481	504	526
- breadth, MLD	ft	72	72	75	77	77	77	82	83	83
- depth, MLD	ft	43	43	43	43	43	43	51	51	51
- draught	ft	22	23	23	23	23	23	23	23	25
Cargo										
- No. of 20' ISO containers		418	418	418	542	542	542	668	668	668
- Cubic stowage in containers (12 tons/container)	cu ft/ton	85	85	85	85	85	85	85	85	85
Power	hp	4,960	9,510	16,080	6,030	11,120	19,030	7,100	13,000	21,980
Fuel Rates										
- Main engines	tons/day	16.7	31.5	53.1	19.7	36.4	63.0	23.6	42.3	72.8
- Auxiliaries (a) (at sea)	tons/day	3.8	4.4	5 1	3.9	4.5	5.4	4.1	4.7	5.7
(in port)	tons/day	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9
Gross tonnage		10,800	10,800	10,800	12,300	12,300	12,300	17,700	17,700	17,700
Container Stowage										
- No. of rows across		6	6	6	7	7	7	7	7	7
- No. of tiers high (deck)		2	2	2	2	2	2	2	2	2
(hold)		5	5	5	5	5	5	6	6	6
Construction cost (variable as at end 1972)	$m	9.1	9.8	10.9	9.7	10.6	11.8	11.2	12.1	13.4
Complement		31	32	33	31	32	33	32	33	34

(a) Auxiliaries consumption rates above are on basis of independent alternators (i.e. - no engine driven alternators), and include an allowance for carriage of about 100 - 20 ft ISO refrig. containers. This is equivalent to auxiliaries consumptions of about 1 ton/day at sea and 3 tons/day in port.

FIGURE E.2
CELLULAR CONTAINER SHIP
TYPICAL LAYOUT



E.5 ROLL ON/ROLL OFF SHIPS

Roll on/roll off ships are designed for a horizontal movement of cargo and, as the name implies, were originally developed to operate in association with road transport (cars, trucks, and semi-trailers). However, with the advent of fork-lift and 'straddle' trucks, such ships have also proved ideally suited for the rapid transportation of containerised, as well as packaged and palletised cargoes.

Advantages include the ability to rapidly handle a wide variety of all types of cargoes, generally in packaged, palletised or containerised form, as well as on road transport. No inbuilt cargo handling facilities are required, which leads to savings in maintenance. A large stern door is provided for loading and discharge of the vehicle deck. More recently, large capacity hoists connecting the vehicle deck and spaces under have been provided to enable these spaces to be utilised for the carriage of cargo. However, this constitutes an interruption to the horizontal cargo flow pattern and is therefore a restriction to rapid loading and discharge of cargo.

Disadvantages are the relatively poor use of cubic capacity and, when a hoist is provided, some restriction of loading and discharge of the hold space. Terminal facilities must be arranged to match the stern loading requirements, and adequate shore transportation facilities must be provided.

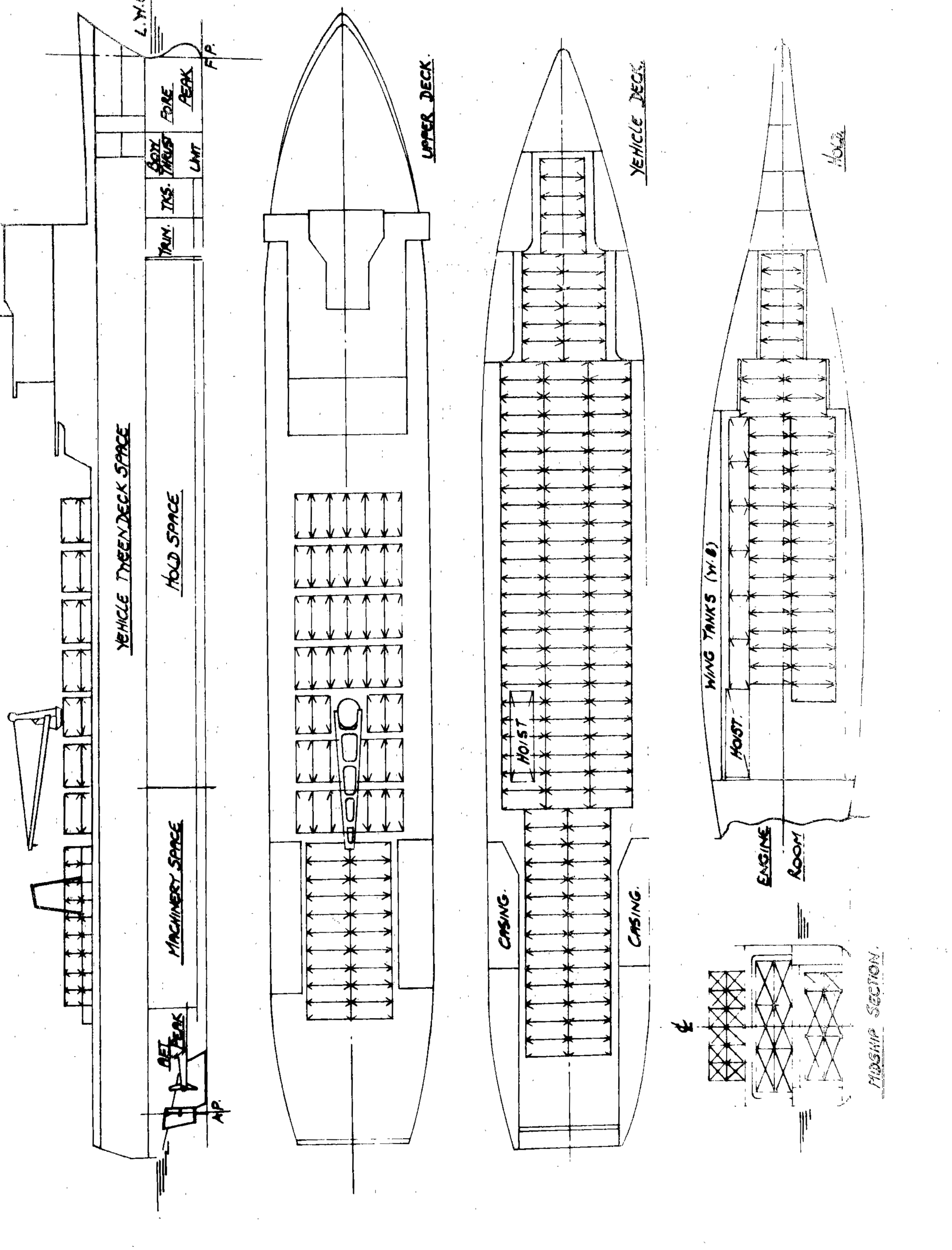
Table E.3 summarises the principal characteristics and indicative costs of alternative sizes of roll on/roll off ships, and Figure E.3 illustrates a typical layout of the type of vessel considered.

TABLE E.3 - ROLL ON/ROLL OFF SHIPS - TWIN SCREW DIESEL

		Cargo weight (tons)								
		3936			5412			6396		
		Service speed (knots)			Service speed (knots)			Service speed (knots)		
		14	17	20	14	17	20	14	17	20
Dimensions										
- length,(BP)	ft	399	409	435	484	491	497	540	556	579
- breadth, MLD	ft	75	75	78	80	82	83	85	85	87
- depth of upper deck MLD	ft	49	49	49	49	49	49	54	54	54
- depth to V'cle deck, MLD	ft	27	27	27	27	27	27	29	29	29
- draught	ft	22	22	23	22	22	23	23	23	23
Cargo										
- No. of 20' ISO containers		340	340	340	460	460	460	540	540	540
- Cubic stowage in containers	cu ft/ton	85	85	85	85	85	85	85	85	85
Power	hp	6,030	10,990	20,100	6,970	12,460	22,110	7,500	14,070	24,120
Fuel Rates										
- Main engines		19.7	36.4	56.0	22.6	41.3	72.8	24.6	46.2	78.7
- Auxiliaries (a) (at sea)	tons/day	3.9	4.5	5.4	4.1	4.7	5.7	4.2	4.9	5.9
(in port)	tons/day	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
Gross tonnage		11,800	11,800	11,800	14,800	14,800	14,800	18,700	18,700	18,700
Construction cost (variable as at end 1972)	$m	10.8	11.6	12.8	12.4	13.0	14.7	13.7	14.4	16.3
Complement		31	32	33	32	33	34	33	34	35

(a) Auxiliaries consumption rates above are on basis of independent alternators (i.e. - no engine driven alternators), and <u>include</u> an allowance for carriage of about 100 - 20 ft ISO refrig. containers. This is equivalent to auxiliaries consumptions of about 1 ton/day at sea and 3 tons/day in port.

FIGURE E.3
ROLL ON/ROLL OFF SHIP
TYPICAL LAYOUT



E.6 BARGE-CARRYING SHIPS (LASH)

This is a highly specialised and high-priced modern concept of sea transportation, developed to suit trading patterns which involved river and coastal barge operations at each or either end. The LASH ship constitutes the 'trade link' over the long ocean-going voyage.

The concept is described by the name LASH (Lighter-Aboard-Ship) and it is just that in simple terms.

The main advantage is fairly high discharge rate of heavy units (barges) enabling rapid turn-round at ports. However, it is a highly sophisticated unit requiring a very large capacity gantry crane to handle the loaded barges to and from the ship, and also a pusher tug to ferry the barges when afloat.

By its very nature, the system involves 'double handling' of sea cargoes at either end. It requires the barges to be loaded (with general, unitised or containerised cargoes) and subsequently the barges as units to be loaded on the LASH ship. While this may be a disadvantage in comparison with other concepts in normal coastal or trans-oceanic transportation, there are obvicus advantages in the special trades referred to above.

However, the intricacies of the concept, involving the provision of a large capacity gantry crane and pusher tug, associated with the high construction costs and rather low utilisation of cubic capacity, generally tend to show this type of ship at disadvantage in comparison with other types on a conventional coastal trade.

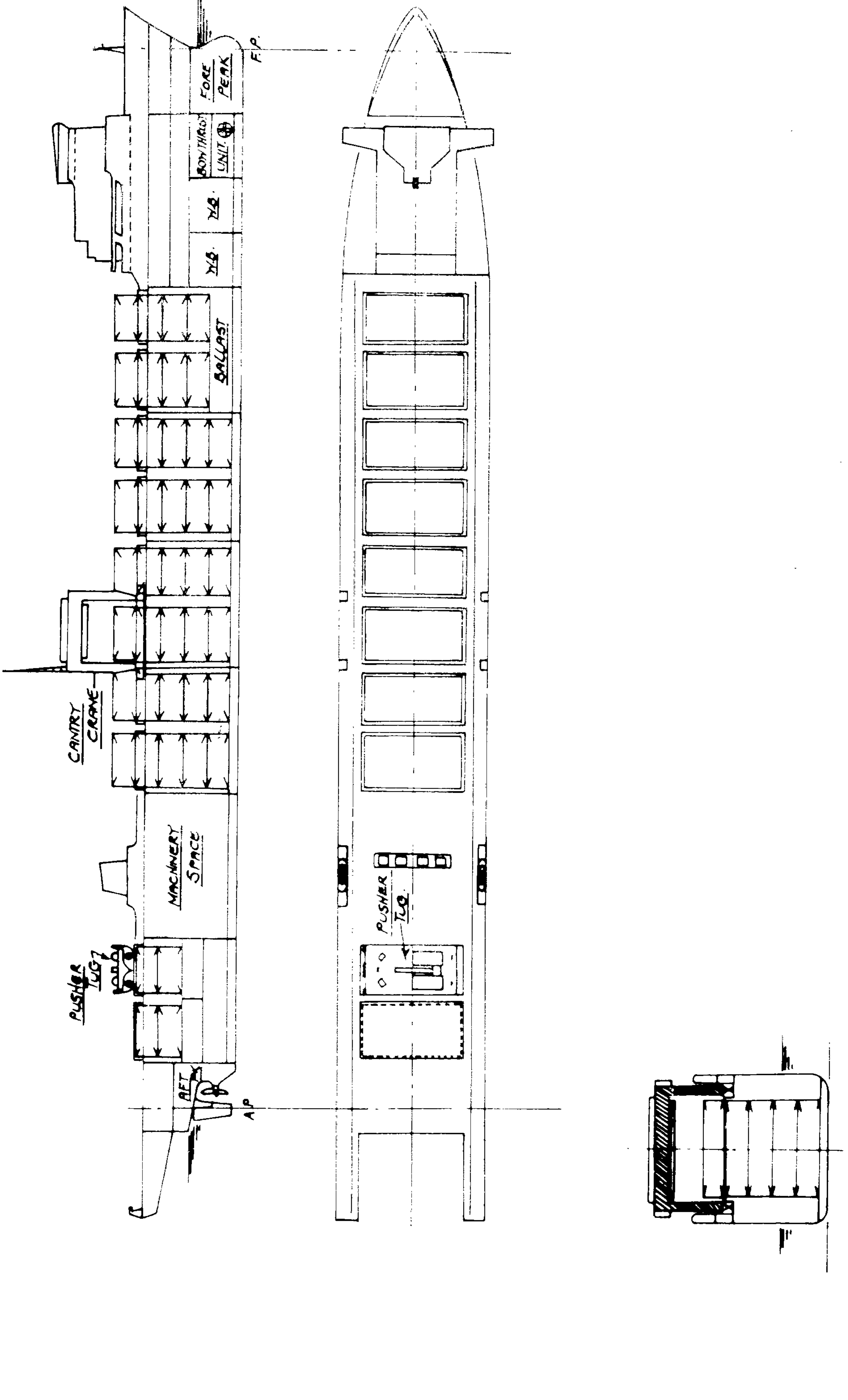
Table E.4 summarises the principal characteristics and indicative costs of alternative sizes of LASH (barge carrying) ships, and Figure E.4 illustrates a typical layout of the type of vessel considered.

TABLE E.4 - LASH CONCEPT - SINGLE SCREW DIESEL

		Cargo weight (tons)								
		3444			4920			6396		
		Service speed (knots)			Service speed (knots)			Service speed (knots)		
		14	17	20	14	17	20	14	17	20
Dimensions										
- length (BP)	ft	435	438	458	500	507	523	523	540	556
- breadth, MLD	ft	74	74	78	78	78	82	85	85	85
- depth, MLD	ft	46	46	46	49	49	49	51	51	51
- draught	ft	22	23	23	23	23	23	23	23	23
Cargo (excl. lighters)										
- no. of lighters		28	28	28	40	40	40	41	41	41
- cargo/lighter	tons	123	123	123	124	124	124	158	158	158
Power	hp	6,030	10,050	20,100	6,970	12,460	22,110	7,500	14,070	24,120
Fuel Rates										
- Main engines	tons/day	20.7	33.5	65.9	22.6	41.3	72.8	24.6	46.2	80.7
- Auxiliaries (a) (at sea)	tons/day	4.0	4.4	5.4	4.1	4.7	5.7	4.2	4.9	4.9
(in port)	tons/day	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8
Gross tonnage		12,800	12,800	12,800	15,300	15,300	15,300	18,200	18,200	18,200
Construction cost (variable as at end of 1972)	$m	16.6	16.5	17.3	18.0	19.0	20.0	20.5	21.5	22.5
Complement		31	32	33	32	33	34	33	34	35

(a) Auxiliaries consumption rates above are on basis of independent alternators (i.e. - no engine driven alternators), and include an allowance for carriage of about 100-20ft ISO refrig. containers. This is equivalent to auxiliaries consumptions of about 1 ton/day at sea and 3 tons/day in port. Also, 'in port' consumption includes 6 tons/day for 250 ton Gantry crane, only used intermittently.

FIGURE E.4
LASH BARGE-CARRYING SHIP
TYPICAL LAYOUT



ANNEX F

EVALUATION OF SHIPPING ALTERNATIVES

F.1 THE SHIPPING PROBLEM

The shipping problem is one of determining the optimal development strategy for WASSS during the period 1975-1990 under various modal split assumptions, involving selection of the optimum vessel type (and its parameters) to be introduced into the fleet as replacements or acquisitions, and also the timing of such changes in fleet composition.

Four vessel types were considered to be appropriate for introduction into the WASSS fleet. These were roll on/roll off, unit load, LASH, and a hybrid container vessel. These vessel types are described in detail in Annex E.

In the analysis of the total transport system, modal split is one of the variables to be determined. In this part of the analysis, a range of modal split is examined. This is then used in the analysis of the total system to determine the optimum modal split. The six cases examined are presented in Table F.1.

TABLE F.1 - ALTERNATIVE MODAL SPLIT ASSUMPTIONS

(% of predicted tonnage accruing to sea)

Case	Pilbara	Kimberley	Darwin
1	80	80	25
2	70	80	25
3	60	80	25
4	50	80	25
5	40	80	25
6	0	80	25

For each modal split, the optimum speed and size for each ship type was selected so as to minimise the present value of the cost of operating a fleet composed of that type over the study period.

Having determined the optimum ship size and speed for each ship type, the ship type having the lowest cost is selected as the sea mode contender in the overall evaluation.

The next section outlines the ship costing information used; the last two sections summarise the analysis and results.

F.2 SHIPPING COSTS

The costs used in this study are resource costs and as such reflect the actual total cost of the resources used. The costs are net of any form of tax or subsidy, and transfer payments are excluded.

In the case of those assets which are used jointly but which are created specifically for only one user, the entire cost of establishment and maintenance is charged against that user. Only those additional costs attributable directly to other users are charged to those users.

Capital costs are included as capital injections at the time of creation of the asset, not as annual charges.

Total shipping costs for purposes of analysis are categorized into vessel, cargo handling, administration and capital. These are considered in detail below for alternative ship types over various size and speed ranges.

F.2.1 Vessel Costs

F.2.1.1 Maintenance and repair

Maintenance and repair cost estimates were based on data for various ship types supplied by Australian shipping companies. The derived cost functions, assumed to apply to all ship types, are summarised in Table F.2.

TABLE F.2 - ANNUAL MAINTENANCE AND REPAIR COST FUNCTIONS

($,000)

Cost category	Function
Hull and superstructure	$(4 + .00144GRT)(1.03)^{t+1}$ (a)
Engines	$(14.5 + .00195SHP)(1.03)^{t+1}$ (b)
Docking and surveys	$(13.5 + .00140GRT)(1.03)^{t+1}$
Equipment and other	$(13.5 + .00528GRT)(1.03)^{t+1}$
TOTAL	$(45.5 + .00812GRT + .00195SHP)(1.03)^{t+1}$

(a) GRT = gross registered tons, and t is the age of the vessel, counting the first year as one. (b) SHP = installed shaft horsepower.

Maintenance and repair costs for containers and lighters have not been included in Table F.2. The cost per annum is 5%

and 7% of capital cost for dry and reefer containers respectively, and 2.5% of capital cost for lighters.

F.2.1.2 Insurance

Insurance costs are broken into two classes, hull/war risk policy costs, and protection/indemnity club costs. Hull and war risk policies vary with replacement costs of the vessel and tend to remain relatively constant in terms of real costs over time. Protection and indemnity club costs tend to vary over time. In both cases, the insurance rates charged depend on the operators' experience and history. Average rates applicable to WASSS were used to estimate cost functions; these are given in Table F.3.

TABLE F.3 - ANNUAL INSURANCE COST FUNCTIONS
($'000)

Cost category	Function
Hull and war risk	.0136 P (a)
Protection and indemnity	.001796GRT (b)
TOTAL	.0136 P + .001796GRT

(a) P = construction cost of vessel. (b) GRT = gross registered tons.

F.2.1.3 Crew and Associated Costs

Crew and associated costs were analysed under the following headings :

(a) salaries and wages less keep deductions,
(b) welfare payments, and
(c) other items comprising victualling, laundry, dry docking, voyage costs, and miscellaneous.

WASSS supplied data which were used to establish a general cost function for crew and associated costs for crew sizes varying between 30 and 36. This function is given below.

ANNUAL CREW AND ASSOCIATED COSTS ($'000) = 467.291+28.09 (N-30)
where N = crew size, over the range 30 to 36.

F.2.1.4 Other Vessel Overheads

Other vessel overheads comprise wireless costs, deck stores, engine stores, and stewards' stores. The cost function estimated from data supplied by WASSS is given below.

OTHER VESSEL OVERHEAD COSTS ($'000) = 19.3 + .0069GRT
where GRT = gross registered tons.

F.2.1.5 Fuel and Lubricants

Fuel and lubricant costs depend on the breakdown of total ship operating time into steaming time, in-port time, and idle time (for docking, surveys and major maintenance). Idle time was taken (on WASSS advice) to be 20 days, thus 345 days are available for scheduled operations. The split between sailing time and in-port time depends on the voyage schedule for each vessel in the fleet.

The cost function, which was estimated using bunker charges applicable at Fremantle, is given below.

ANNUAL FUEL AND LUBRICANT COSTS ($'000) = 21 + 233.62 LP
+ (205.22H - 233.62(LP - LS)) R

where LP = tons of light fuel per hour in port,
LS = tons of light fuel per hour at sea,
H = tons of heavy fuel per hour, and
R = proportion of effective operating time per annum ship spends steaming.

F.2.1.6 Harbour and Wharf Dues

In most shipping operations, harbour and wharf dues comprise a capital charge component and a maintenance and repair component. In a resource cost analysis the capital charge component is included as a capital injection at the time of creation of the wharf or harbour, not as an annual charge. Therefore this component is included in the capital cost section.

The second component is included in the cargo handling cost section.

F.2.2 Cargo Handling Costs

Detailed estimates of cargo handling costs, and the methods of estimation used are given in Annex H.

F.2.3 Administration Costs

A detailed analysis of administrative costs under alternative modal split assumptions and for various ship types has not been undertaken for the purposes of this study. It has been assumed that the current level of $650,000 per annum will persist for all alternatives in the future. This assumption was adopted on the grounds that the relative magnitude of these costs is such that moderate fluctuations would have an insignificant effect on the results of the study.

F.2.4 Capital Costs

F.2.4.1 Ship Capital Costs

Ship capital costs have been estimated by the Shipbuilding Division of the Department of Transport. The costs quoted pertain to construction costs in Australian shipyards.

Details of the estimation methods and the resultant vessel statistics for alternative ship types over various size and speed ranges are in Annex E.

F.2.4.2 Port Capital Costs

The port capital costs included in this study are those incurred in providing additional wharf facilities for WASSS operations. For example, a new port is to be constructed in the Port Walcott area regardless of WASSS operations. None of these developmental costs are attributable to WASSS. If special facilities are required for WASSS operations, for example, a stern loading ramp for roll on/roll off operations, these costs must be charged to WASSS. Costs of port development are outlined below for the alternative ship types under consideration.

Unit load and hybrid container vessels incur no additional port development costs over the project period.

Roll on/roll off vessels require the installation of either a new berth or a stern ramp at all outports. The Public Works Department of Western Australia estimated requirements and costs for each of the ports of call. Several alternative development proposals were submitted for each port. Table F.4 shows the costs of the cheapest alternative in each case.

TABLE F.4 - PORT DEVELOPMENT COSTS FOR ROLL ON/ROLL OFF VESSELS

($'000)

Port	Development cost
Port Walcott	996
Port Hedland	1,325
Broome	680
Wyndham	1,096
Port Warrender	1,334
Darwin	600

In a LASH operation in Western Australia, barge terminals must be established at all ports. The costs of providing these facilities were based on data supplied by WASSS. These costs are shown in Table F.5.

TABLE F.5 - PORT DEVELOPMENT COSTS FOR LASH VESSELS

($'000)

Port	Development cost
Fremantle	1,970
Port Walcott	1,110
Port Hedland	1,210
Broome	120
Wyndham	680
Port Warrender	120
Darwin	1,000

F.2.4.3 Container, Pallet and Lighter Capital Costs

The capital costs of containers and pallets are presented in Table F.6. Lighter capital costs are included in the vessel capital costs at Annex E.

The stock of containers and pallets required at any time was assumed to be 1.5 times the actual requirements, where this is based on the cargo deadweight capacity of each ship in the fleet, and the load form assumed.

Other items such as slings, cages, etc., are minor cost items and are not considered.

TABLE F.6 - CAPITAL COSTS OF CONTAINERS AND PALLETS

Item	Cost ($ per unit)	Expected life (years)
Dry containers (a)	1,400	7
Reefer containers	7,500	7
Pallets (b)	5	2

(a) Container costs are the cheapest per unit costs. (b) Pallets are of wooden construction.

F.3 ASSUMPTIONS, METHODS AND RESULTS

This section deals with the assumptions made, and the methods used to determine the optimum fleet development for WASSS for each of the alternative modal split patterns.

F.3.1 Assumptions

In past operations, WASSS has serviced a large number of ports. Recently, however, much has been done to rationalise the service and reduce this number. We assume that this rationalisation will continue with the introduction of modern specialist ships and new materials handling methods and equipment.

F.3.1.1 Ports of Call

The ports of call considered are Port Walcott (an upgraded or new port is to be established in the near future to service the Dampier/Wickham area), Port Hedland, Broome, Wyndham, Port Warrender (developments in the Admiralty Gulf region are assumed to require regular servicing by WASSS from 1980 onwards) and Darwin. Regions currently serviced through other ports will be serviced by a combination of road and lightering operations from the above ports.

F.3.1.2 Cargo Movements

The projected cargo movements by sea from Perth to each of the ports above were calculated for each of the six modal split cases given in Table F.1. As an example, the cargo movement corresponding to Case 1 is presented in Table F.7. Other cargo movements, both interport and cargoes from the outports to Perth, have in WASSS operations comprised about 10% of total cargo shipped. These cargoes are treated implicitly in the computation of in-port time.

TABLE F.7 PROJECTION OF CARGO FOR MOVEMENT BY SEA TO THE NW PORTS, CASE 1[(a)]

('000 tons)

Year	Port Walcott	Port Hedland	Total Pilbara	Broome	Wyndham (b)	Port Warrender	Darwin	Total Kimberley & Darwin
1975	89.6	82.5	172.1	32.5	31.8		55.5	119.8
1976	116.2	107.8	224.0	34.1	30.6		60.4	125.1
1977	123.5	134.0	257.5	36.6	30.2		65.5	132.3
1978	134.5	136.2	270.7	40.1	33.3		70.9	144.3
1979	140.6	132.0	272.8	43.1	40.0		76.7	159.8
1980	142.2	126.8	269.0	46.2	34.2	12.7	82.7	175.6
1981	153.5	128.4	281.9	48.6	35.8	8.3	89.1	181.8
1982	159.7	130.5	290.2	51.0	37.6	15.4	95.9	199.8
1983	165.3	125.7	291.0	54.6	39.7	16.0	103.0	213.3
1984	168.4	132.1	300.5	57.3	41.7	16.6	110.4	226.0
1985	171.9	126.2	298.1	69.0	43.6	17.3	118.2	248.1
1986	183.4	123.0	306.4	61.8	45.8	32.9	126.4	266.9
1987	191.1	124.2	315.3	71.6	47.8	29.9	134.9	284.2
1988	198.1	124.5	322.6	64.9	49.7	29.0	143.8	287.4
1989	198.1	124.5	322.6	64.9	49.7	29.0	143.8	287.4
1990	198.1	124.5	322.6	64.9	49.7	29.0	143.8	287.4

(a) The modal split assumptions represented by Case 1 are defined in Table F.1. (b) Port Warrender cargoes are assumed to be discharged at Wyndham until 1980.

The projected cargo movements are presented, and analysed, in aggregate form (demand predictions were actually made in a less aggregated form; refer to Annexes C and D). However, cargo densities have not been ignored. The mean stowage rate of cargo to be forwarded is about 90 cu ft per ton. In the light of this, new vessels have been designed with cargo deadweight capacities based on an average stowage rate of 80 cu ft per ton, which, in the opinion of the Shipbuilding Division, is the maximum attainable. One consequence is that some cargoes must be considered to be captive to other modes and this is reflected in the maximum modal share to any destination being held at 80%.

We have assumed that cargo demand may be considered to be uniformly distributed through the year. Past operations of WASSS would tend to suggest the existence of a seasonal pattern of demand. However, this could be attributable, to some extent at least, to the vulnerability of WASSS vessels to seasonal weather disturbances at that time. New vessels will not be so adversely affected.

F.3.1.3 Schedules

Scheduling of vessels was studied in some detail with the aid of a simulation model. This indicated that fleet requirements could be reduced substantially from those under a 'bus stop' to all ports schedule by scheduling each vessel with varying numbers of port calls on each voyage. This also had the effect of increasing the periodicity of calls at each port.

Unfortunately, it was impractical to use this approach for the large number of alternatives studied. A compromise was reached whereby fleet requirements in each year were examined under two schedule forms. The first was a 'bus stop' calling at all ports listed in Section F.1 of this Annex. The second schedule was made up of two types of voyages, one calling exclusively at the Pilbara ports and the other at the Kimberley ports and Darwin. This schedule is referred to as 'shuttle'.

In each case, fleet requirements were based on three considerations. Firstly, a uniform fleet in terms of ship type, size and speed was aimed at. Secondly, the average load factor was taken to be 90% of cargo deadweight capacity. Thirdly, a port call periodicity of between six and eight days was required.

F.3.1.4 Time in Port

In-port times were analysed in three parts : port delays, loading and discharging time and in-port down time.

Port delays comprise manoeuvring time, labour disputes, berth shortages, weather, crew disputes, tidal delays, mooring time and miscellaneous. Unit load, hybrid container, and roll on/roll off ships may be expected to have similar total delay times. Average delay times in days per voyage for these ship types are given in Table F.8.

TABLE F.8 - AVERAGE DELAY TIMES: UNIT LOAD, HYBRID CONTAINER AND RO/RO VESSELS (a)

(Days per voyage)

	Bus stop, all ports	Shuttle	
		Pilbara	Kimberley, Darwin
Without Port Warrender	1.19	.51	.85
With Port Warrender	1.36	.51	1.02

(a) These figures are based upon average port delays incurred in current WASSS operations.

LASH vessels will be subject to different port delay times. These are considered later.

Loading and discharging times depend on the vessel type, on the percentages of cargo containerised, unitised, and break bulk, on stowage rates and on cargo handling equipment and methods. The rates calculated assume a labour force equivalent of 3 gangs at Fremantle and 2 gangs at each outport, with a level of productivity per gang hour based on East Australian standards. Loading and discharge rates for the unit loaders currently employed in WASSS are based on those actually achieved. The rates for the new ships applied data developed in Annex H. The rates calculated are presented in Table F.9. Rates applicable to LASH vessels will be considered later.

TABLE F.9 - LOADING AND DISCHARGE RATES FOR ALTERNATIVE SHIP TYPES (a)

(tons/hr)

	RO/RO	Hybrid container	Unit load (b)	Unit load (c)
Fremantle	180	162	45	60 + 2k (d)
Outports	103	62	36	45 + 2k (d)

(a) These rates allow for the time involved in loading and discharging of empty containers and cargo for return to Perth. (b) This column applies to unit load vessels currently in use. (c) This column is for new unit loaders. (d) k = 0,1,2, ..., 15 for project years 1975, 76, 77, ..., 90.

In-port downtime in coastal shipping operations comprises a significant proportion of annual effective operating time. It is a function of the voyage schedule and instituional labour arrangements in each port of call. In this study it is assumed that each gang can work two consecutive shifts of 8 hours each with no Sunday or holiday work. To allow for in-port downtime, the loading or discharge rates were multiplied by a factor of .563 to give a rate per hour which reflects these institutional labour arrangements.

In the case of LASH vessels, the total in-port time was rather more difficult to compute. As well as a fixed component due to port delays, and, depending on the voyage schedule, an in-port downtime component, there is a variable component which varies particularly with the number of barges to be discharged and loaded. Our data base was inadequate to derive accurate estimates for each component and each port of call. From the available data, an overall estimate of total in-port time of 3 hours per barge loaded or discharged was derived. Preparing schedules of the LASH operation using this figure, and comparing them with schedules prepared by WASSS for a similar LASH operation, indicated that a reasonable approximation of in-port time had been derived.

F.3.2 Analysis

The analysis of alternative development strategies for WASSS was carried out in two parts. Phase 1 of the analysis was used to select the optimal ship type and its parameters for use in alternative fleet development strategies, for which four sea modal shares were examined, Cases 1,3, 5 and 6 (Table F.1). Phase 2 consisted of a detailed analysis of the selected ship type.

F.3.2.1 Phase 1

Two simplifying assumptions were made in this part of the analysis. Firstly, the total construction cost of a vessel was attributed to the year of introduction of that vessel. Secondly, in the case of unit load vessels, the loading and discharge rates were assumed not to vary with time. The rates used were the mid-range values of those presented in Table F.9.

Each ship type was examined over its size and speed range as given in Annex E. To avoid complications in this preliminary phase arising from analysis of the operation of mixed fleets, participation by the WASSS fleet of four unit loaders was ignored. Fleet requirements were built up for each year of the project period for each of the bus stop and shuttle schedules. For each ship size and speed present values of vessel costs were derived at the discount rates 5, 7 and 10 per cent. It was in this way that a size/speed trade-off could be obtained, and the optimum ship parameters selected.

Having obtained the optimal ship parameters for each ship type, and the present value of vessel costs, it was now necessary to obtain the present values for containers and pallets, cargo handling costs, and port capital costs for each of the alternative ship types. These three cost categories were not included in the size/speed trade-off analysis because they were invariant to ship size and speed. It was now possible to select the optimum ship type to be used in each alternative modal split case. In Table F.10 are the results of the preliminary analysis for Case 1. Table F.11 presents a summary of results for the other cases studies in this phase.

The main features of these results were:

(i) The unit load ship type was clearly to be preferred over the other types. The next best was the hybrid container type, costing about 10% more.

(ii) The high productivity of LASH and RO/RO was reflected in the smaller fleets required, but this economy was nullified by the higher vessel construction costs.

TABLE F.10 - PRELIMINARY ANALYSIS OF FOUR ALTERNATIVE SHIP TYPES: RESULTS FOR CASE 1[(a)]

Vessel statistics	RO/RO				Hybrid Container			
	Bustop	Shuttle			Bustop	Shuttle		
		Pilbara	Kimberley	Total		Pilbara	Kimberley	Total
Cargo capacity dwt	5,904	5,904	5,904		6,396	4,920	4,920	
Speed knots	17	17	17		14	14	14	
Voyage time days	17.06	11.36	16.60		22.71	13.70	20.00	
Inport time days	7.29	6.61	6.95		10.84	7.93	8.27	
Trips annually	20	30	20		15	25	17	
Fleet requirements in year (number)								
1975	3	2	2	4	4	2	2	4
1976	4	2	2	4	4	2	2	4
1977	4	2	2	4	5	3	2	5
1978	4	2	2	4	5	3	2	5
1979	5	2	2	4	5	3	3	6
1980	5	2	2	4	6	3	3	6
1981	5	2	2	4	6	3	3	6
1982	5	2	2	4	6	3	3	6
1983	5	2	2	4	6	3	3	6
1984	5	2	3	5	6	3	3	6
1985	6	2	3	5	7	3	4	7
1986	6	2	3	5	7	3	4	7
1987	6	2	3	5	7	3	4	7
1988	6	2	3	5	7	3	4	7
1989	6	2	3	5	8	3	4	7
1990	6	3	3	5	8	3	5	8
PRESENT VALUE ($m)								
at 5%								
Vessel costs	119.8			105.5	107.4			101.5
Containers etc.	10.0			9.0	13.0			10.1
Cargo handling	29.5			29.5	26.0			26.0
Port capital	1.3			1.3				
Total	160.6			145.3	146.4			137.6
at 7%								
Vessel costs	106.0			93.6	94.9			89.6
Containers etc.	8.2			7.5	10.8			8.4
Cargo handling	23.9			23.9	21.0			21.0
Port capital	1.0			1.0				
Total	139.1			126.0	126.7			119.0
at 10%								
Vessel costs	89.4			79.5	79.9			75.5
Containers etc.	6.6			5.8	8.4			6.6
Cargo handling	17.7			17.7	15.6			15.6
Port capital	.7			.7				
Total	144.0			103.7	103.9			97.7

(a) The modal split assumptions represented by Case 1 are defined in the text at Table F.1.

NOTE: Simple scheduling has been used with no allowance for the present fleet.

Vessel statistics	LASH				Unit Load			
	Bustop	Shuttle			Bustop	Shuttle		
		Pilbara	Kimberley	Total		Pilbara	Kimberley	Total
Cargo capacity dwt	6,396	5,904	5,904		6,888	5,904	5,904	
Speed knots	18	15	15		15	14	14	
Voyage time days	14.36	10.51	15.07		26.10	18.14	24.43	
Inport time days	5.13	5.13	5.13		15.02	12.37	12.71	
Trips annually	24	32	21		13	19	14	
Fleet requirements in year (number)								
1975	3	1	2	3	4	2	2	4
1976	3	2	2	4	5	3	2	5
1977	3	2	2	4	5	3	2	5
1978	3	2	2	4	6	3	2	5
1979	4	2	2	4	6	3	3	6
1980	4	2	2	4	6	3	3	6
1981	4	2	2	4	6	3	3	6
1982	4	2	2	4	7	3	3	6
1983	4	2	2	4	7	3	3	6
1984	4	2	2	4	7	3	3	6
1985	4	2	3	5	7	3	4	7
1986	5	2	3	5	7	3	4	7
1987	5	2	3	5	8	4	4	8
1988	5	2	3	5	8	4	4	8
1989	5	2	3	5	8	4	4	8
1990	5	2	3	5	8	4	5	9
PRESENT VALUES ($m)								
at 5%								
Vessel costs	134.5			126.7	96.8			87.7
Containers etc.	5.2			5.1	9.0			7.5
Cargo handling	25.6			25.6	30.4			30.4
Port capital	1.6			1.6				
Total	166.9			159.0	136.2			125.6
at 7%								
Vessel costs	120.1			113.5	85.2			77.1
Containers etc.	4.3			4.3	7.5			6.2
Cargo handling	20.7			20.7	24.6			24.6
Port capital	1.3			1.3				
Total	146.4			139.8	117.3			107.9
at 10%								
Vessel costs	102.6			97.6	71.4			64.5
Containers etc.	3.4			3.4	5.9			4.8
Cargo handling	15.4			15.4	18.3			18.3
Port capital	.9			.9				
Total	121.3			117.3	95.6			87.6

(a) The modal split assumptions represented by Case 1 are defined in the text at Table F.1.

NOTE: Simple scheduling has been used with no allowance for the present fleet.

TABLE F.11 - PRELIMINARY ANALYSIS OF FOUR ALTERNATIVE SHIP TYPES: RESULTS FOR CASES 3, 5 and 6[a]

		RO/RO		Hybrid		Lash		Unit Load	
		Bustop	Shuttle	Bustop	Shuttle	Bustop	Shuttle	Bustop	Shuttle
Case 3									
Vessel Statistics									
Cargo dwt	tons	5,904	4,428	6,888	6,396	6,396	6,396	6,888	5,904
Speed	knots	17	14	15	15	18	19	15	14
Present Values									
5%	$m	138.9	131.2	124.8	119.7	140.1	146.8	115.8	112.7
7%	$m	120.3	113.8	107.9	103.7	124.2	128.3	99.5	96.8
10%	$m	98.8	93.7	88.4	85.3	102.8	104.1	80.8	78.7
Case 5									
Vessel Statistics									
Cargo dwt	tons	5,904	5,904	6,888	6,396	6,396	6,396	6,888	5,904
Speed	knots	17	17	15	15	18	19	15	14
Present Values									
5%	$m	122.8	115.9	114.6	115.7	126.5	125.0	103.2	102.2
7%	$m	106.1	97.2	96.2	100.0	110.6	109.7	88.6	87.8
10%	$m	86.7	79.5	78.8	81.9	91.9	90.9	71.9	71.2
Case 6									
Vessel Statistics									
Cargo dwt	tons		5,904		6,888		6,396		6,888
Speed	knots		16		16		19		14
Present Values									
5%	$m		75.5		67.4		81.2		59.3
7%	$m		65.4		58.6		70.8		51.1
10%	$m		53.2		47.9		59.7		41.6

(a) The modal split assumptions represented by Cases 3, 5 and 6 are defined in the text at Table F.1.

NOTE: Simple scheduling has been used with no allowance for the present fleet.

F.3.2.2 Phase 2

The results of the Phase 1 analysis meant that Phase 2 involved a detailed analysis of alternative development strategies using unit loaders. This analysis differed in several respects from the Phase 1 analysis.

Firstly, the existence of the anticipated WASSS fleet in 1975 was recognised. This required additional analysis to phase out the old unit loaders. These vessels were imported and are subject to Government regulations concerning re-exportation and replacement by Australian-built ships. The requirement is for orders to be placed with Australian shipyards for the building of vessels to replace these vessels within five years of the import date. It is estimated that the latest replacement dates for these vessels will be 1978, 1979, 1980 and 1981. Economic analysis has indicated that these vessels should not be replaced before these dates.

Secondly, in considering ship capital costs, it is assumed that 35% of the capital cost is incurred in the year of delivery, 40% in the year prior to the year of delivery, and the remaining 25% two years prior to the delivery date. This split approximates to the normal resource use distribution in ship construction.

Thirdly, loading and discharge rates are now allowed to vary over time. This change could result in a change in the optimal ship parameters, but does not lead to a change in the optimal ship type. However, the ship parameters determined in Phase 1 of the analysis were carried over to Phase 2 with one exception. It was found that for Case 6, ships to the Kimberley only, the optimum size reverted to 6,000 tons when the more detailed analysis of Phase 2 was applied.

The analysis was again performed for the 'bus stop' and 'shuttle' schedules in each case. As before, the results indicated that the 'bus stop' schedule was inferior to a 'shuttle' service, except for one or two years at the beginning of the study period; at this time, the fleet size is only four or five ships which are better utilised in a 'bus stop' schedule.

F.3.3 Results

Table F.12 shows the final phasing of withdrawal of present WASSS ships from the fleet and the timing of new ship acquisition, as estimated from the Phase 2 analysis. Six cases are presented, corresponding to the range of sea modal shares listed in Table F.1.

The corresponding total cost profiles are summarised in Table F.13.

TABLE F.12-FINAL ANALYSIS OF UNIT LOAD SHIP:
FLEET COMPOSITION AND USAGE UNDER ALTERNATIVE MODAL SPLIT ASSUMPTION FOR CASES 1 to 6[a]

(Number of vessels)

Year 19 -	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
Case 1																
Vessel aquisitions	1	1		1	1	1	1			1						
Vessel sales				1	1	1	1									
Vessels in fleet	5	6	6	6	6	6	6	6	6	7	7	7	7	7	7	7
Fleet usage - A	5															
- B		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
- C		3	3	3	3	3	3	3	3	4	4	4	4	4	4	4
Case 2																
Vessel aquisitions	1	1		1	1	1	1			1						
Vessel sales				1	1	1	1									
Vessels in fleet	5	6	6	6	6	6	6	6	6	7	7	7	7	7	7	7
Fleet usage - A	5															
- B		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
- C		3	3	3	3	3	3	3	3	4	4	4	4	4	4	4
Case 3																
Vessel aquisitions	1		1	1	1	1	1			1						
Vessel sales				1	1	1	1									
Vessels in fleet	5	5	6	6	6	6	6	6	6	7	7	7	7	7	7	7
Fleet usage - A	5	5														
- B			3	3	3	3	3	3	3	3	3	3	3	3	3	3
- C			3	3	3	3	3	3	3	4	4	4	4	4	4	4
Case 4																
Vessel aquisitions		1		1	1	1	1			1						
Vessel sales				1	1	1	1									
Vessels in fleet	4	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6
Fleet usage - A	4															
- B		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
- C		3	3	3	3	3	3	3	3	4	4	4	4	4	4	4
Case 5																
Vessel aquisitions			1	1	1	1	1			1						
Vessel sales				1	1	1	1									
Vessels in fleet	4	4	5	5	5	5	5	5	5	6	6	6	6	6	6	6
Fleet usage - A	4	4														
- B			2	2	2	2	2	2	2	2	2	2	2	2	2	2
- C			3	3	3	3	3	3	3	4	4	4	4	4	4	4
Case 6																
Vessel aquisitions				1		1	1			1						
Vessel sales	1			1		1	1									
Vessels in fleet	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4
Fleet usage - C	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4

(a) The modal split assumptions represented by Cases 1 to 6 are defined in Table F.1

NOTE: Fleet usage gives the number of vessels employed in each of the voyage types A, B, and C, where A is bustop all ports, B is shuttle to the Pilbara, and C is shuttle to the Kimberley and Darwin.

TABLE F.13 - FINAL ANALYSIS OF UNIT LOAD SHIP: PRESENT VALUE OF CAPITAL AND OPERATING COSTS FOR PILBARA, KIMBERLEY, AND DARWIN CARGOES FOR CASES 1 to 6[a]

($ million)

Discount rate	Capital costs				Operating costs				
	Vessel acquisition	Containers and pallets	Vessel sales	Total	Vessel associated costs	Containers	Admin-istration	Cargo handling	Total
Case 1									
7%	25.6	4.2	-1.9	27.8	41.7	1.2	5.0	24.5	72.5
10%	23.4	3.3	-1.6	25.3	31.3	0.9	3.8	18.2	54.2
Case 2									
7%	25.5	4.2	-1.9	27.8	41.7	1.2	5.0	22.7	70.7
10%	23.6	3.3	-1.6	25.3	31.3	0.9	3.8	16.9	52.8
Case 3									
7%	25.1	4.1	-1.9	27.2	40.1	1.2	5.0	20.9	67.9
10%	23.0	3.2	-1.6	24.6	30.7	0.8	3.8	15.5	50.9
Case 4									
7%	20.1	3.3	-1.9	21.5	34.9	1.0	5.0	19.1	60.0
10%	18.3	2.6	-1.6	19.3	26.1	0.7	3.8	14.1	44.8
Case 5									
7%	19.8	2.7	-1.9	20.1	34.2	1.0	5.0	17.3	57.5
10%	17.7	2.5	-1.6	18.7	25.5	0.7	3.8	12.8	42.8
Case 6									
7%	11.7	2.0	-2.5	11.1	22.2	0.6	5.0	10.1	38.0
10%	10.4	1.5	-2.1	9.7	16.6	0.4	3.8	7.4	28.3

(a) The modal split assumptions represented by Cases 1 to 6 are defined in Table F.1.

ANNEX G

CARGO HANDLING, MATERIALS HANDLING AND PORT FACILITIES FOR ALTERNATIVE SHIP TYPES

G.1 SUMMARY

This Annex examines the port facilities and materials handling systems and equipment required for a shipping service between Fremantle and NW Australia ports and Darwin for 1975 to 1990.

For each port, the proportions are established of cargo which would be carried in large freight containers, unit loads and as miscellaneous cargo. The basic assumptions were checked with Australian National Line.

Port facilities requirements include strengthening of decks for specialised materials handling equipment (hybrid container, RO/RO, unit load ships), special RO/RO berths and LASH barge unloading terminals, shore-based container and miscellaneous cargo storage facilities, and covered areas for break-bulk and consolidation.

Cargo handling rates depend upon the type of cargo, ship type, handling equipment, gang size, number of cranes or hatches being worked, and whether work is at Fremantle or outports. Rates for different ship types were established in conjunction with Australian National Line.

Materials handling systems comprise equipment for handling cargo from ship's side or vehicle deck and transfer to shore-based terminal. Basic capital and operating costs are specified.

For the unit load ship schedules and unit costs of proposed materials handling equipment requirements and terminal

facilities are presented for the major sea participation case, Case 1 of Table F.1, corresponding to 80% modal share to both the Pilbara and Kimberley, and 25% to Darwin. This detail is omitted for the other ship types. The costs are then reduced to a rate per ton of cargo which are then applied to the range of sea modal shares covered by the study. For completeness, the rates for all the ship types and ports are also tabulated at the end of this Annex.

Diagrammatic representations of the layout of a shipping terminal and operational materials handling systems for the four ship types are attached (Figures G.1 to G.6).

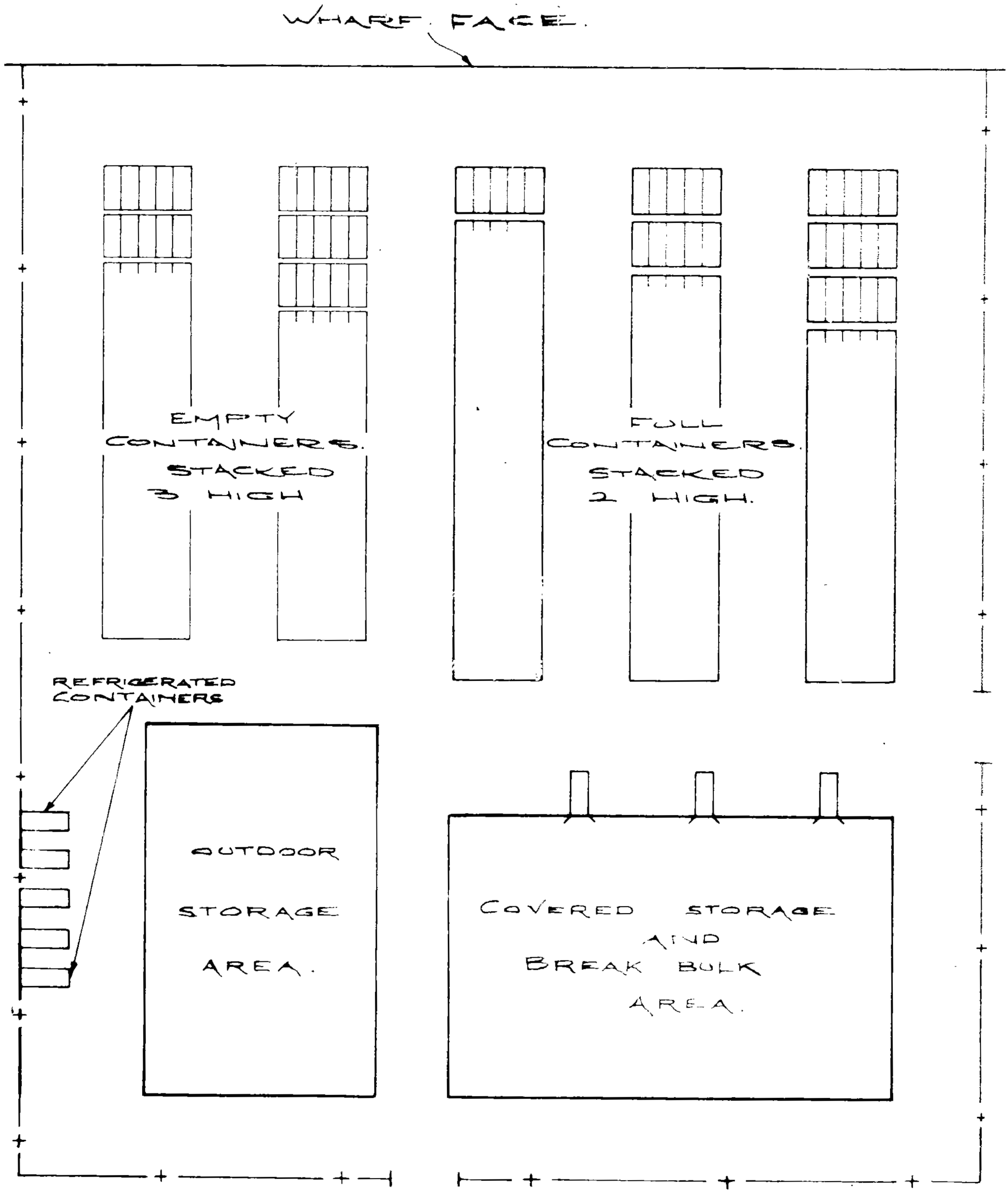
G.2 LOAD FORMS

The following load forms were assumed:

Unitisable	-	suitable for palletising, strapping, or slinging for handling as a unit (also pallet cages and containers up to 3 tons). Average weight of unit load is 2 tons.
Containerisable	-	suitable for ISO 20 ft container dry and reefer types of large collapsible container flats. Average weight 12 tons.
Other	-	large items handled singly. Average lift estimated at 4 tons.

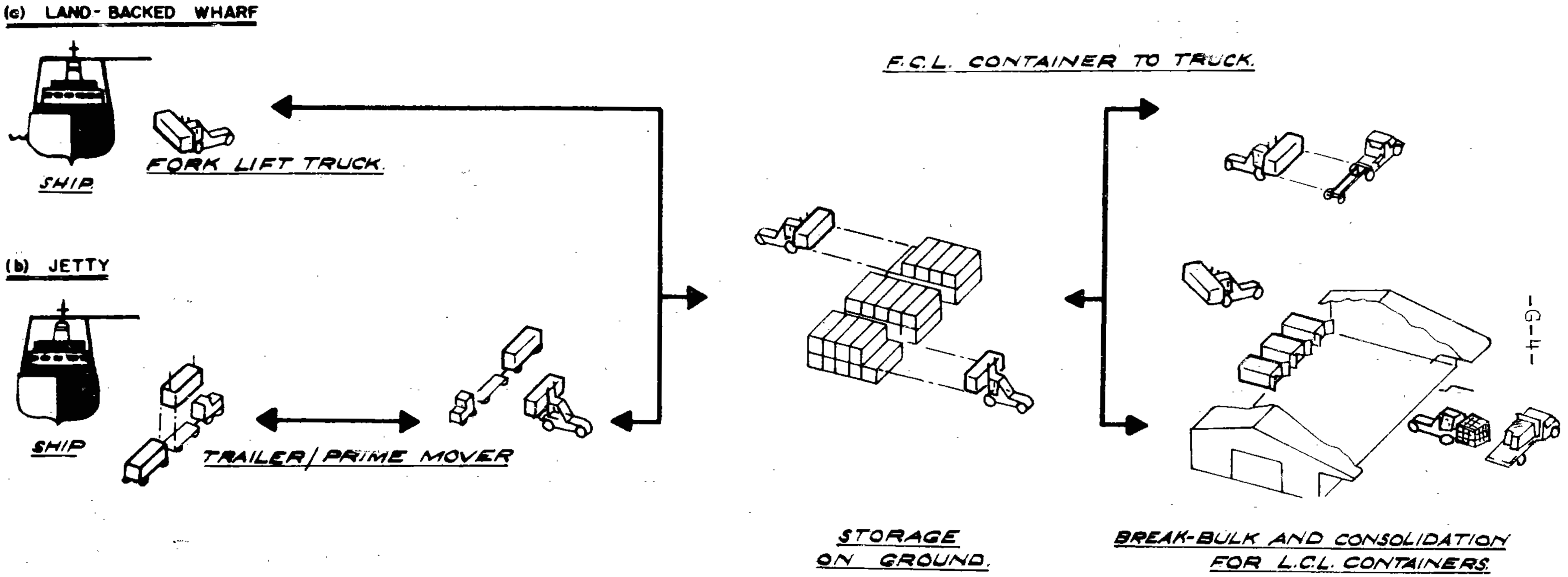
G.3 CARGO CHARACTERISTICS

The cargo densities shown in Table G.1 were assumed for the main cargo categories. Also included in this table are the maximum percentages of these categories which are amenable to movement either as unit loads or in containers.

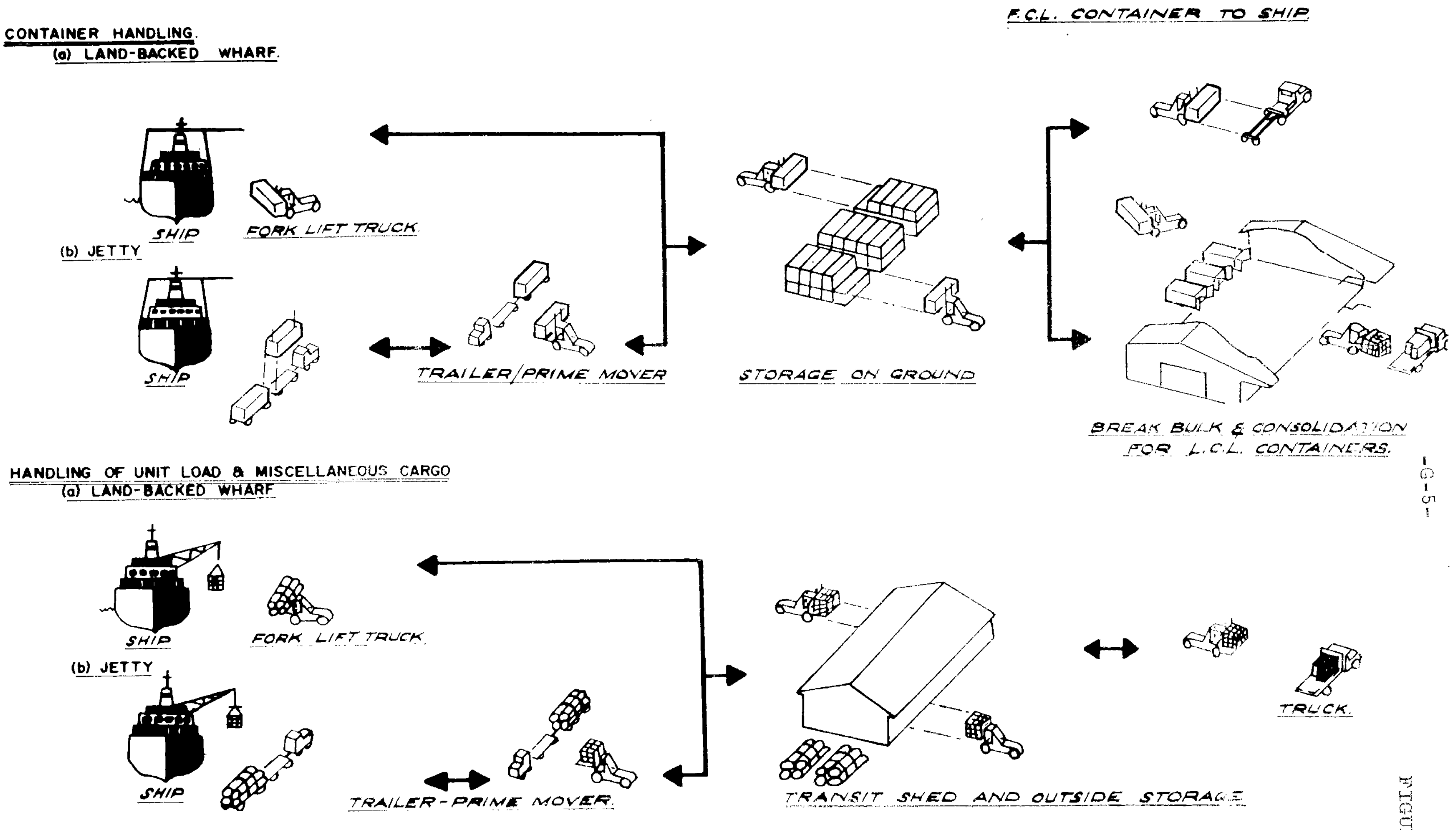


TYPICAL LAYOUT OF SHIPPING TERMINAL.

FIGURE G.2

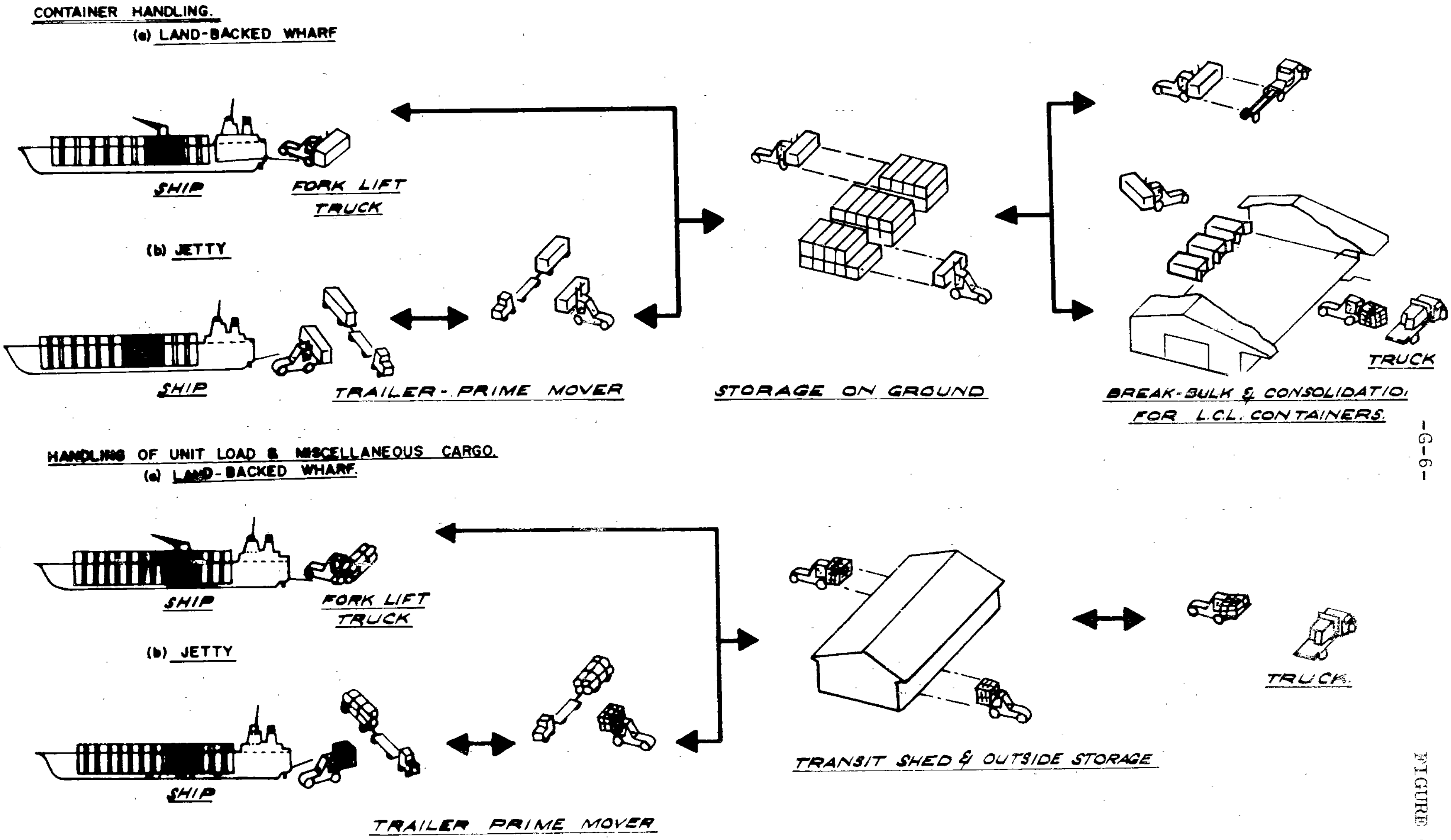


OPERATIONAL DIAGRAM 1 - CELLULAR CONTAINER SHIP.



OPERATIONAL DIAGRAM 2 - HYBRID CELLULAR CONTAINER SHIP

FIGURE G.3

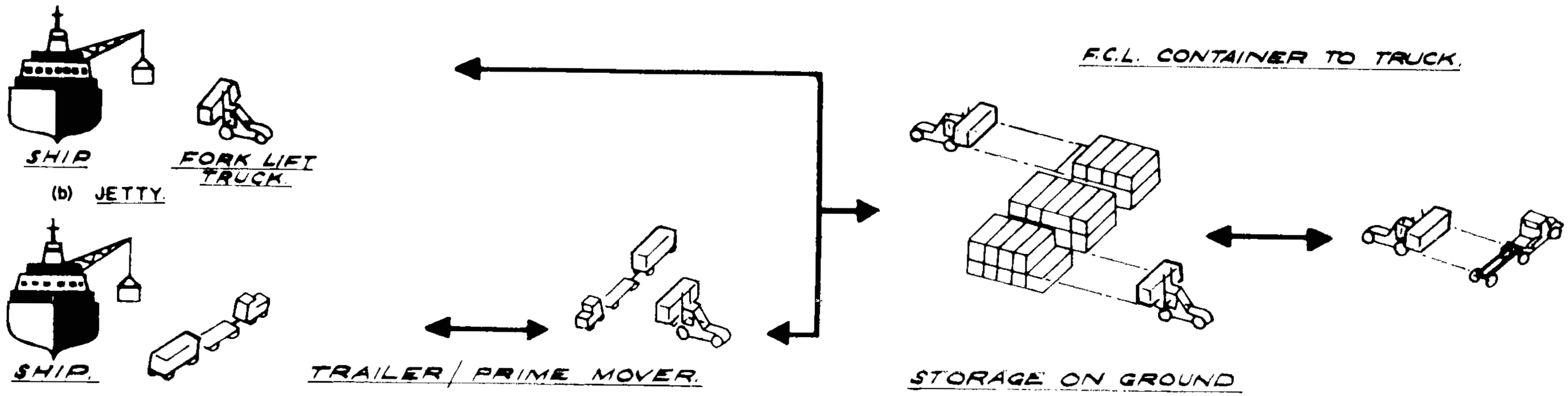


OPERATIONAL DIAGRAM 3 — ROLL-ON/ROLL-OFF SHIP.

FIGURE G.4

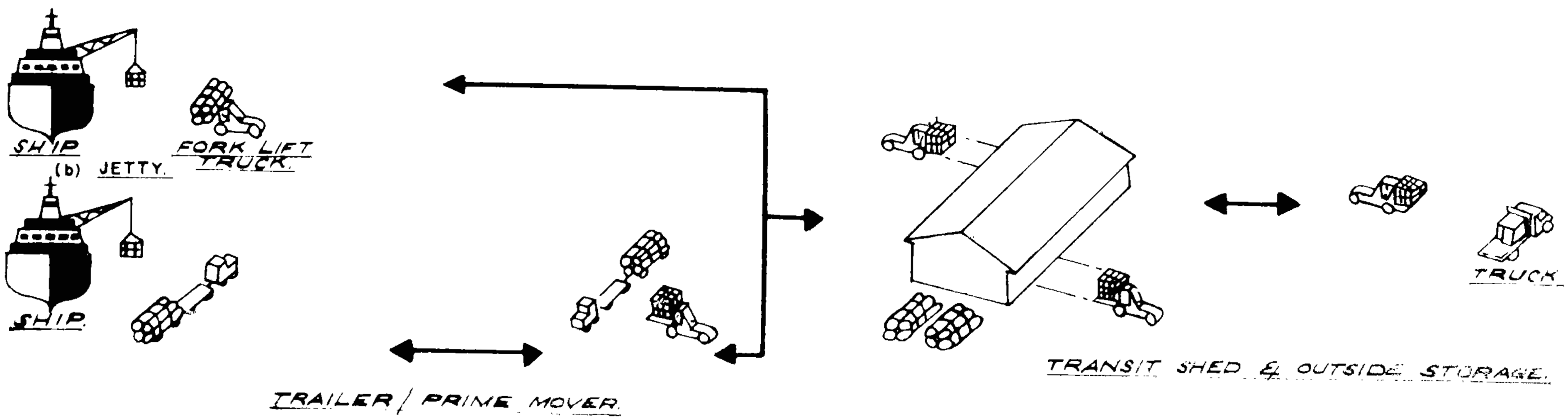
CONTAINER HANDLING.

(a) LAND-BACKED WHARF



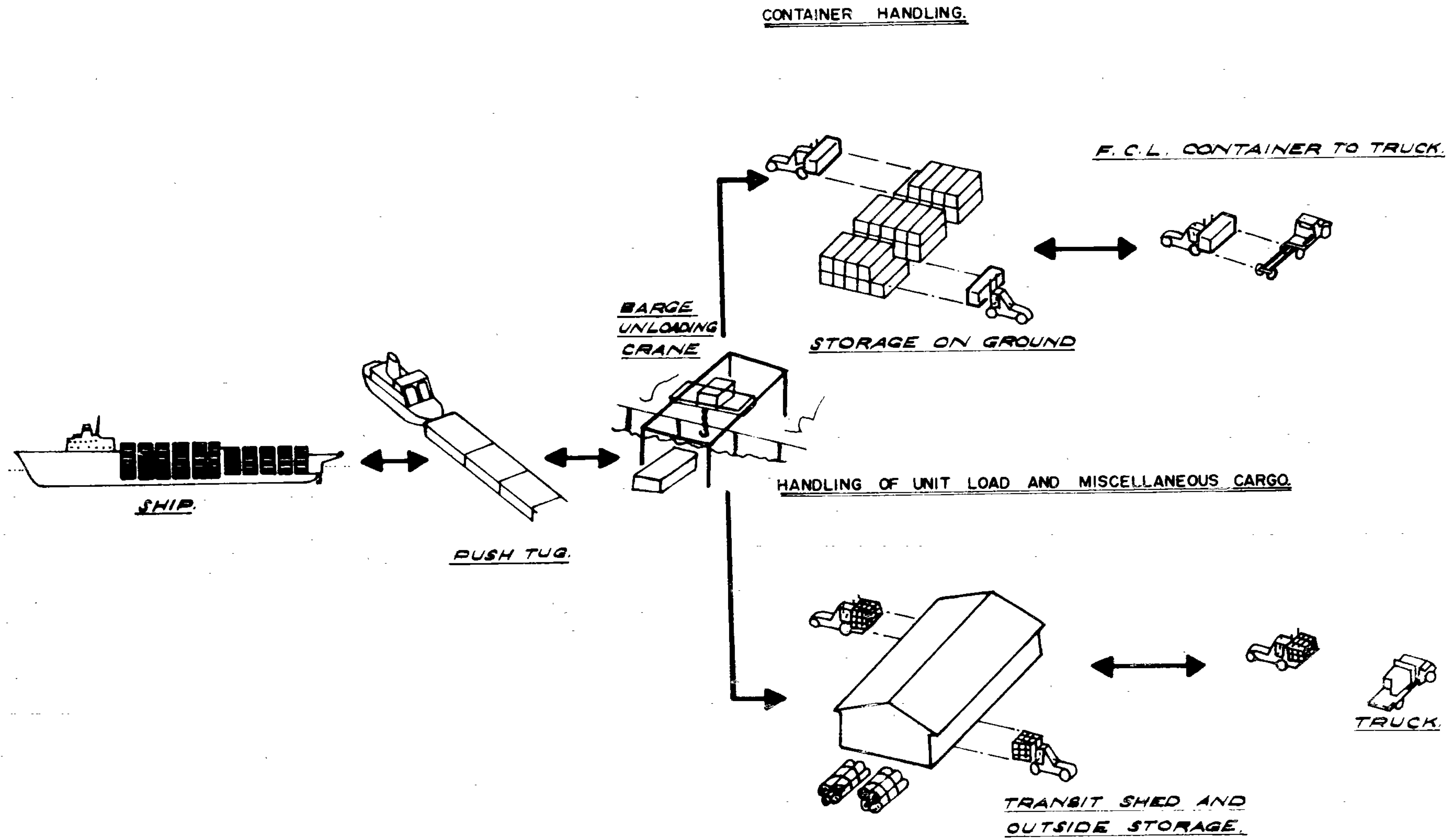
HANDLING OF UNIT LOAD & MISCELLANEOUS CARGO.

(a) LAND-BACKED WHARF



OPERATIONAL DIAGRAM 4 - UNIT LOAD SHIP.

FIGURE -G-7-



OPERATIONAL DIAGRAM 5 - L.A.S.H. SHIP.

FIGURE G.6

TABLE G.1 - PERCENTAGE OF CARGO CATEGORIES

	Logistics	Maintenance	Construction	Housing
Density cu ft/ton	100	100	60	60
Unitisable %	90	20	50	70
Containerisable %	100	25	40	60

To simplify computing procedures, a fixed breakdown between break-bulk and through movement was assumed for each port. Through movement in this context implies direct delivery to consignee from the wharf; break-bulk requires an intermediate stage in a covered terminal. These assumptions, together with those pertaining to the calculated percentages delivered to the port as unit loads or containers are shown in table G.2 below.

TABLE G.2 - PERCENTAGE OF CARGO AT PORTS

(Percent)

	Port Walcott	Port Hedland	Broome	Wyndham	Darwin
Break-bulk	50	60	60	30	50
Through movement	50	40	40	70	50
Unitisable	63	61	69	72	76
Containerisable	66	64	71	77	79

Break-bulk estimates are made on basis of domestic consumption at the port towns.

For unit load ships, it was assumed that the percentage of containerised cargo increased by 2% per annum from 25% in 1975 to

55% in 1990. At any time all goods suitable for containers are assumed to be containerised for hybrid, RO/RO and LASH.

G.4 BASIC MATERIALS HANDLING EQUIPMENT REQUIREMENTS

The National Materials Handling Bureau (NMHB) derived the basic materials handling equipment requirements and costs shown in Tables G.3 and G.4.

TABLE G.3 - MATERIALS HANDLING EQUIPMENT PROPOSALS AND COSTS

Item	Proposed to handle	Capital cost ($)	Operating cost ($ per hour)
50,000 lb fork lift truck	Full containers at all ports; ships side, terminal area, ship to terminal	75,000	5.00
20,000 lb fork lift truck	Empty containers at all ports	28,000	1.75
5,000 lb fork lift truck (low mast)	Break-bulk stowing and unstowing of ISO containers	12,000	0.70
Tow tractor	Cargo under hook	6,000	0.30
20 ton trailer (a)	Cargo under hook	3,500	0.15
25 ton mobile crane	Miscellaneous cargo	115,000	6.00
22.5 ton overhead crane	Miscellaneous cargo	(b) 40,000	

(a) pneumatic tyres (b) including erection of steel work.

TABLE G.4 - CONTAINER AND PALLET COSTS

Item	Capital cost ($)	Operating cost ($ p.a.)
20 ft ISO dry containers	1,400	70
20 ft ISO reefer containers	7,500	525
48 in wooden pallets	5	-

G.5 STORAGE AREAS

National Materials Handling Bureau derived storage area requirements for containerised and other cargo as shown in Table G.5.

TABLE G.5 - STORAGE AREA REQUIREMENTS

	Load	
	Unit and non-containerised	Containers
Outdoor	30 sq ft/ton	Outgoing (full) 2 high Incoming (empty) 3 high Aisle 30-40 ft
Covered	30 sq ft/ton	400 sq ft/container

G.6 SHIP'S GEAR HANDLING

The average rates at which the various ship's gear could handle cargo were estimated as outlined in Table G.6.

TABLE G.6 - SHIP'S GEAR HANDLING RATES

	Unit cargo (tons/hr/ crane)		Containers/hr/ crane (20 ft conts)		Other cargo (tons/hr/crane)	
	Frem (a)	Out (b)	Frem (a)	Out (b)	Frem (a)	Out (b)
Hybrid	25	20	(d) 8	(d) 6	50	40
RO/RO(c)			(e)20	(e)17	80	70
Unit loader(f)	25	20	5	4	50	40
LASH	30	30	5	5	40	40

(a) Fremantle.(b) Outports.(c) All 3 cranes operating at Fremantle simultaneously; any 2 cranes operating simultaneously at outports. (d) Vehicle deck and deck crane operating at all ports. (e) This figure includes flats. (f) 3 hatches operating simultaneously at Fremantle; 2 hatches operating simultaneously at outports.

G.7 MATERIALS HANDLING EQUIPMENT REQUIRED AT PORTS

National Materials Handling Bureau estimated the number of fork-lift trucks, tow tractors and trailers required for each type of ship at all the ports. As an example, those for the unit load ship are given in Table G.7 below, for a typical year, 1985.

TABLE G.7 SCHEDULE OF MATERIAL HANDLING EQUIPMENT REQUIREMENTS IN 1985, FOR UNIT LOAD SHIP OPERATING AT SEA MODAL SHARE CORRESPONDING TO CASE 1, TABLE F.1.

(Number)

Port	Fork-lift trucks			Tow tractor	20 ton trailer
	50,000lbs	20,000lbs	5,000lbs		
Fremantle	3	1	8		
Port Walcott					
- wharf (a)	2		4		
- jetty		2	4	4	8
Port Hedland	2		4		
Broome	1		3	4	8
Wyndham	1		3	4	8
Darwin	2		4	4	8

(a) If a land-backed wharf is constructed, otherwise jetty.

G.8 STORAGE REQUIREMENTS AT THE PORTS

Applying the basic requirements given in Table G.4, the total storage requirements at the ports were calculated for all ship types. Those for the unit load ship are given in Table G.8.

TABLE G.8 SCHEDULE OF TERMINAL FACILITIES FOR UNIT LOAD SHIPS

(Thousands of square feet)

Year	Fremantle			Port Walcott			Port Hedland		
	Out. (a)	Cov. (b)	Tot. (c)	Out. (a)	Cov. (b)	Tot. (c)	Out. (a)	Cov. (b)	Tot. (c)
1975	113	68	181	39	21	60	40	23	63
1980	195	92	287	63	31	94	50	24	74
1985	254	104	358	90	35	125	65	26	91
1990	298	106	404	109	37	146	68	23	91

Year	Broome			Wyndham			Darwin		
	Out. (a)	Cov. (b)	Tot. (c)	Out. (a)	Cov. (b)	Tot. (c)	Out. (a)	Cov. (b)	Tot. (c)
1975	18	8	26	18	7	25	28	13	41
1980	25	10	35	25	10	35	40	16	56
1985	39	14	53	26	8	34	67	22	89
1990	39	10	49	33	9	42	100	27	127

(a) Outside storage. (b) Covered storage. (c) Total storage.

ANNEX H

CARGO HANDLING COSTS

The actual cargo handling cost incurred in a specific year is a function of the economies of scale and the degree of labour and equipment resources utilization. The cost varies significantly over time (but within a decreasing range) as capacity can only be expanded by large discrete units. However, for simplicity, the derived costs were ultimately reduced to a per ton cargo rate and applied to all sea modal share cases.

H.1 CARGO HANDLING COST CATEGORIES

H.1.1 Port structure maintenance was estimated by allocating existing costs on a ship gross registered tonnage basis and allocating 5% of initial costs of additional investment on a tonnage handled basis.

H.1.2 Covered and open storage costs were estimated by calculating a unit cost per unit area, allocating the cost per ton throughput over 15 years with no structure scrap value, and including 10% of initial cost per year as a land rent.

H.1.3 Terminal infrastructure costs were obtained by taking a base management cost and allocating additional costs presently incurred on a unit cost per ton of cargo handled.

H.1.4 Terminal maintenance costs were assumed to be 5% of the initial capital costs of the storage area requirements, on a per unit area basis.

H.1.5 Equipment capital charges were estimated assuming a six year replacement cycle, 15% scrap value, and an 8% interest rate.

H.1.6 Equipment operating costs were calculated from presently experienced unit costs by estimating the theoretical annual utilization of the equipment and adding 15% to allow for breakdowns and intraterminal movements.

H.1.7 Stevedoring costs were calculated from an hourly labour cost of $3.50 plus 50% benefit loading, 3 gangs working 105% of ship on berth time in Fremantle and 2 gangs working 115% at outports. It was assumed gangs worked 56 manhours per shift. No attempt was made to estimate the costs of minimum guaranteed working time.Thus the calculated costs are marginally lower than those currently experienced at outports.

The unit cargo handling costs for the four ship types, by port are given in Tables H.1 to H.7.

TABLE H.1 - FREMANTLE UNIT CARGO HANDLING COSTS

($ per ton)

	Hybrid Container	Ro/Ro	Unit Load	Lash
Port structure maintenance	.240	.655	.240	.095
Covered storage costs	.123	.123	.084	.084
Open storage costs	.085	.085	.061	.061
Terminal infrastructure	.107	.107	.107	.107
Terminal maintenance	.086	.086	.061	.061
Equipment capital charges	.346	.425	.237	.197
Equipment operating costs	.237	.221	.248	.217
Stevedoring costs	1.238	1.311	1.647	1.635
TOTAL	2.462	3.013	2.685	2.457

TABLE H.2 - PORT WALCOTT UNIT CARGO HANDLING COSTS

($ per ton)

	Hybrid Container	Ro/Ro	Unit Load	Lash
Port structure maintenance	.268	.787	.268	.102
Covered storage costs	.118	.118	.085	.085
Open storage costs	.100	.100	.059	.059
Terminal infrastructure	.182	.182	.182	.182
Terminal maintenance	.091	.091	.060	.060
Equipment capital charges	.756	.760	.822	.501
Equipment operating costs	.305	.164	.678	.502
Stevedoring costs	2.031	1.437	2.540	1.613
TOTAL	3.851	3.639	4.694	3.104

TABLE H.3 - PORT HEDLAND UNIT CARGO HANDLING COSTS

($ per ton)

	Hybrid Container	Ro/Ro	Unit Load	Lash
Port structure maintenance	.278	.885	.278	.105
Covered storage costs	.134	.134	.085	.085
Open storage costs	.102	.102	.061	.061
Terminal infrastructure	.181	.181	.181	.181
Terminal maintenance	.077	.077	.061	.061
Equipment capital charges	.549	.549	.451	.646
Equipment operating costs	.182	.097	.303	.517
Stevedoring costs	1.662	1.048	2.158	1.608
TOTAL	3.165	3.073	3.578	3.264

TABLE H.4 - BROOME UNIT CARGO HANDLING COSTS

($ per ton)

	Hybrid Container	Ro/Ro	Unit Load	Lash
Port structure maintenance	.285	1.044	.285	.115
Covered storage costs	.142	.142	.083	.083
Open storage costs	.106	.106	.071	.071
Terminal infrastructure	.238	.238	.238	.238
Terminal maintenance	.103	.103	.064	.064
Equipment capital charges	.932	1.012	.864	1.590
Equipment operating costs	.238	.125	.220	.443
Stevedoring costs	1.567	1.015	2.289	1.893
TOTAL	3.611	3.785	4.114	4.497

TABLE H.5 - WYNDHAM UNIT CARGO HANDLING COSTS

($ per ton)

	Hybrid Container	Ro/Ro	Unit Load	Lash
Port structure maintenance	.287	1.325	.278	.108
Covered storage costs	.083	.083	.083	.083
Open storage costs	.105	.105	.071	.071
Terminal infrastructure	.211	.211	.211	.211
Terminal maintenance	.078	.078	.064	.064
Equipment capital charges	.928	1.287	.860	.860
Equipment operating costs	.238	.173	.220	.222
Stevedoring costs	1.704	1.245	2.658	1.865
TOTAL	3.634	4.507	4.454	3.515

TABLE H.6 - PORT WARRENDER UNIT CARGO HANDLING COSTS

($ per ton)

	Hybrid Container	Ro/Ro	Unit Load	Lash
Port structure maintenance	.280	.890	.280	.105
Covered storage costs	.138	.138	.084	.084
Open storage costs	.105	.105	.065	.065
Terminal infrastructure	.205	.205	.205	.205
Terminal maintenance	.085	.085	.062	.062
Equipment capital charges	.625	.625	.511	.738
Equipment operating costs	.199	.110	.251	.485
Stevedoring costs	1.675	1.192	2.310	1.921
TOTAL	3.312	3.350	3.768	3.665

TABLE H.7 - DARWIN UNIT CARGO HANDLING COSTS

($ per ton)

	Hybrid Container	Ro/Ro	Unit Load	Lash
Port structure maintenance	.250	.921	.250	.105
Covered storage costs	.122	.122	.078	.078
Open storage costs	.111	.111	.067	.067
Terminal infrastructure	.182	.182	.182	.182
Terminal maintenance	.097	.097	.060	.060
Equipment capital charges	.586	.673	.796	.646
Equipment operating costs	.128	.143	.264	.354
Stevedoring costs	1.467	1.893	2.540	1.689
TOTAL	2.943	4.142	4.237	3.181

ANNEX I

ROAD TRANSPORT

I.1 INTRODUCTION

There are two relatively recent studies which considered the economics of road trains operating to the north of Western Australia.

The study 'Report on Road Transport Costs Perth to the Pilbara Area' (M.C.G. Schrader, 1968) concluded that the operation of double-bottom road trains to the Pilbara would lower truck operating costs from $58.10 per ton to $45.00 per ton (1968 prices). These costs include fuel tax, sales tax and road maintenance tax. The study recommended that permissible overall semi-trailer length be increased to 53ft subject to a trailer length of 35ft and that double bottoms should be permitted on the North West Coastal Highway north of Northampton. Provided that safe operations could be proved, operation of triple bottoms under the same conditions as double bottoms was recommended.

The 'Report of a Study Group on Ways and Means of Exploiting Economies of Scale in Road Transport Vehicles for Certain Tasks in WA' (Salter, 1970) recommended the operation of 40ft tandem axle trailers in conjunction with a long wheel base prime mover (150in - 200in). It was recommended that double bottoms be permitted to operate north of Geraldton and Meekatharra, and triple bottoms (maximum length 145ft) be permitted in areas where 145ft road trains (with rigid prime mover and trailers) already operate.

As a result of the two studies and previous usage under permit, certain configurations are allowed (by permit) to operate over certain routes in the north as follows :

Articulated vehicles (a prime mover and a semi-trailer) with one trailer and motor wagons with two trailers, both with a maximum length of 100ft, can operate north of Geraldton, Mullewa, Wubin, and Leonora to major towns in the north. Articulated vehicles with two trailers and motor wagons with three trailers, both with an allowable maximum length of 132ft, can only operate north of Carnarvon and Meekatharra to major northern towns. The latter categories are not permitted to operate on the Roebourne-Wittenoom- Tom Price-Paraburdoo-Nanutarra Road.

A further study, 'Report on Optimum Axle Load Analysis for the Pilbara Region - September 1971' (Maunsell and Partners, 1971) concluded that :

(a) The problems of tyre and vehicle design, and regulations limiting the maximum vehicle width place a probable upper limit of between 22 and 24 tons to the tandem axle load. Above this value vehicles may become less stable and a greater hindrance to other traffic.

(b) A tandem axle load of 19 tons is the minimum required to economically justify bitumen sealing of the inland road system.

Research on the economics of axle load is being undertaken on behalf of the National Association of Australian State Road Authorities. The BTE is represented on the Road Load Economics Steering Committee which is monitoring the axle load research. Pending the outcome of that research, we decided not to consider axle loads greater than 16 tons.

I.2 TRUCK OPERATING COSTS

I.2.1 References

A questionnaire was forwarded to major WA trucking companies through the WA Road Transport Association in an attempt to update some of the figures derived in the Schrader report.

The replies were interpreted in the light of reference works such as 'Cost Functions and Optimal Technology for Inter City Highway Transportation Systems' (Armando Lago, Traffic Quarterly, 1968), 'Economic Analysis of Highways' (Robley Winfrey), the Schrader report and several more recent highway analyses. BTE also used published lists of truck and tyre performances and prices, fuel costs, etc.

Taxes were deducted to enable resource costs to be identified. For example, road maintenance costs themselves would be substituted for the road maintenance tax. Vehicle registration, trip permits, etc., have also been excluded.

I.2.2 Assumptions

As the law currently stands, the number of trailers allowed is variable in WA. Because of the complexity of operations and the difficulty of administering this arrangement in the future, we have assumed that single bottoms are used to Geraldton and Wubin and double bottoms to all points north. A 16 ton tandem axle load is assumed throughout although, since we only assume a 90% utilisation, the average axle load comes down to approximately 14 tons. Even this is above the legal limit for roads south of Wubin and Geraldton, but because overload permits are readily available for through loads to the north, it was assumed that no rearrangement of loads would be necessary. Given the use of detachable dollies (or bogies), a change from single bottom operation south of Wubin and Geraldton to double bottoms to the north can also be made without transfer of loads.

Truck utilisation and speed of delivery is primarily determined by the number of drivers on the vehicle; although one-man operation leads to a lower delivery cost, the delivery time is correspondingly longer. It was assumed that 'logistic' deliveries, because of their greater emphasis on cost saving, would use one-man operation, whereas 'development' deliveries, for which time is important, would use two-man operation.

I.2.3 Capital Costs and Depreciation

Power requirements were based on wind resistance (a vehicle height of 12 feet was assumed), frictional losses of the engine and at the road surface, and average grade (assumed varying between 0-1% for the total trip to Pilbara).

Given estimated power requirements, list prices for trucks typical of the types used in the north west, and the answers to the questionnaire, vehicle prices and average speeds were estimated.

Truck life was based on answers to the questionnaire giving an average 600,000 miles on bitumen and an estimated half of this on dirt. In order to simplify computing procedures, truck residual values, as given by the questionnaire, were transformed into a proportional increase of total truck mileage. Thus, for example, a quoted life of 450,000 miles with an associated residual value of $5,000 and $20,000 initial cost would be transformed into a life of 600,000 miles with zero residual value.

Trailer costs were also provided. The life of a typical trailer was taken as 950,000 miles on bitumen roads and 475,000 on dirt.

Given initial costs and the lives calculated as above, capital costs are incorporated into the final linear programming procedures (Annex K) as a variable cost. This simplification is possible because investment in trucks is being made continuously in relatively small increments compared with ships or railway construction.

For operations involved in transporting development tonnages, we assumed that extra trailers are available so that prime movers can go on working unhampered by terminal holdups. In logistic operations, this cannot be done because the driver tends to stay with his truck while it is being unloaded. This is the reason for the differences between the cost components of the logistic and development operations, shown at the end of this Annex.

The number of usable hours per annum was determined by drivers' hours. This is the reason why the capital cost component of one-man operation is higher than for two-man operation.

Insurance costs were taken from State Government Insurance Office data and allocated per mile as indicated above. Assumptions included 33 1/3% no claim bonus and fire fighting equipment installed as a necessary precaution.

I.2.4 Fuel Consumption

Fuel consumption depends on the brake horse power output and efficiency of the motor. Estimates have been provided of about four pounds of diesel per brake horse power hour which were translated to gallons at 7.2 pounds per gallon.

The calculations were further based on taking a loaded and unloaded rate, and also assuming about 10 miles per hour speed reduction on dirt as compared with bitumen.

Comparisons of the calculated figures with road operators' experience gave good correlation on bitumen but the dirt estimate appeared too high. An adjustment of 20% was applied in this case to conform with experience; the fuel consumption calculated in this way agreed with corresponding figures used by the Commonwealth Bureau of Roads.

Fuel costs vary with distance from port and it appeared reasonable to assume an average distribution cost of five cents per gallon as an increment to the Perth price.

Bulk buying and discount, typically up to four cents per gallon, reflect economies of scale. Two cents per gallon was assumed.

Tax on all forms of distillate is approximately 17.5 cents per gallon. A typical calculation of resource cost of fuel would the be of the form:

(City Price)		(Distribution)	(Discount)		(Tax)		(Resource Cost)
45	+	5	-	2	-17.5	=	30.5 cents/gal

I.2.5 Tyres

The introduction of radials (steel cord) over the past few years has brought a considerable increase in tyre life over most analysts' predictions.

Difficulty in assessing variations of tyre life on bitumen and dirt is increased because tyre wear is proportional to speed. On the assumption that truck speed average was 10 mph less for dirt than bitumen with the same load, theoretical calculation on a per mile basis from Armando Lago gave figures close to the average from all other sources. The factor employed for tyre life on dirt is 60% of tyre life on bitumen.

The lowest tyre cost given in response to our questionnaire was three cents/mile for a semi-trailer and the highest 9.6 cents for a 16 tyre combination, both on bitumen. A major tyre supplier has suggested about three recaps per tyre and

60,000 miles per tread on bitumen. This would give an extremely low cost per mile of .145 cents per tyre. Assuming a more conservative single recap and a 15% discount on bulk buying of new tyres, a figure of .183 cents per tyre per mile was derived.

Operators suggest that drive wheels sustain greater wear and calculations on their figures give a 25% increased cost. Schrader has assumed extra heavy duty tyres at 10% increased cost would be used. The 25% increase suggested by the operators was used.

Sales tax has been removed from the tabled results which are shown later.

I.2.6 Repairs and Maintenance of Trucks and Trailers

For prime movers, oiling and greasing are generally taken as directly related to fuel consumption. Survey of available sources of data indicated that a lubrication cost of 10% of fuel cost would be representative. This, together with other repair and maintenance costs derived from operator's data, came to 6.25 cents per mile for a prime mover hauling one trailer on bitumen. This cost is a function firstly of road type and secondly of the number of trailers hauled, reflected mainly as power requirement. Operators' data suggested a factor of 2 for dirt roads and factors of 1.4 and 1.7 for double and triple trailers respectively. These were the factors assumed.

For trailers, operators' data was again used. The basic costs on bitumen were assumed as 0.8 cents and 1.25 cents per mile for semi-trailers and full trailer respectively, with a factor of 1.75 for operations on dirt.

Because we are looking at resource costs, it was necessary to get a breakdown of this figure into oil, labour and component parts in order to extract the relevant taxes.

The average labour content indicated by the results of the questionnaire was 48.6 per cent. 3.5% payroll tax was subtracted from labour costs, and sales tax removed from the parts component.

I.2.7 Driver Hours Pay, and Truck Hours

As mentioned previously, truck utilisation is a function of one-man or two-man operation. This is reflected in the 'truck hours' column in Table I.1. Overtime payments to drivers are paid on a basis of hours of driving in excess of the basic daily quota, as covered by industrial awards. All time spent in the cab not driving, for two-man operation, is paid at the normal rate. These are the bases of the estimates of driver hours shown in Table I.1.

TABLE I.1 - TRUCK HOURS DRIVEN PER WEEK AND DRIVER PAID HOURS

Road surface	Truck hours (a)		Driver paid hours (b)	
	One-man	Two-man	One-man	Two-man
Dirt	61.5	118.0	74.5	259.0
Bitumen	69.0	133.0	86.0	298.0

(a) About 8% has been subtracted for refuelling, tyre checks, punctures,etc. (b) Equivalent hours at standard rate.

I.2.8 Overheads

Most data examined indicated that overheads were generally calculated as a proportion of total costs excluding overheads. Presumably this covers head office expenses such as management, buildings, publicity and accounting. It is not usually clear whether or not terminal distribution is included.

A simplifying assumption would be to take the same terminal distribution costs per ton for all modes. The scale of trucking operations in the north west is such that the line-haul vehicle would not be used for local distribution, and large multi-load consignments would probably be left at a transit area for subsequent distribution, just as in railway or ship transport. Final distribution costs within a port or mine town were therefore neglected for all modes. For trucks, overheads were costed as 12% of total costs excluding overheads.

I.2.9 Total Truck Operating Costs

Total truck operating costs are detailed in Table I.2.

TABLE I.2 - RESOURCE COSTS OF TRUCK OPERATION ON DIRT AND BITUMEN ROADS FOR GOODS ASSOCIATED WITH THE DEVELOPMENT OF A PROJECT AND FOR LOGISTIC SUPPORT

(Cents per mile)

Cost	Dirt				Bitumen			
	Development		Logistics		Development		Logistics	
	one man	two men	one man	two men	one man	two men	one man	two men
				SINGLE BOTTOM				
Fuel	6.78	6.78	6.78	6.78	5.65	5.65	5.65	5.65
Tyres	5.35	5.35	5.35	5.35	3.18	3.18	3.18	3.18
Repairs & maintenance								
- Truck								
oil	.76	.76	.76	.76	.63	.63	.63	.63
labour	5.31	5.31	5.31	5.31	2.54	2.54	2.54	2.54
parts	5.31	5.31	5.31	5.31	2.54	2.54	2.54	2.54
- Trailer								
labour	0.63	0.63	0.63	0.63	0.36	0.36	0.36	0.36
parts	0.63	0.63	0.63	0.63	0.36	0.36	0.36	0.36
Driver(s)								
- wages	4.84	4.84	)	)	4.46	4.46	)	)
- allowances	1.28	1.34	)12.99	)17.73	1.06	1.10	)12.42	) 16.87
- overtime	0.91	5.11	)	)	0.97	4.91	)	)
Insurances	0.73	0.38	0.95	0.47	0.60	0.31	0.81	0.39
overhead	3.80	4.1	4.4	4.7	2.8	3.1	3.4	3.7
Operating component	36.33	40.54	43.11	47.67	25.15	29.14	31.89	36.22
Capital component	9.0	9.0	12.8	12.8	4.5	4.5	6.4	6.4
TOTAL	45.33	49.54	55.91	60.47	29.65	33.64	38.29	42.62
				DOUBLE BOTTOM				
Fuel	9.37	9.37	9.37	9.37	7.85	7.85	7.85	7.85
Tyres	9.62	9.62	9.62	9.62	5.74	5.74	5.74	5.74
Repairs & maintenance								
- Truck								
oil	1.08	1.08	1.08	1.08	0.89	0.89	0.89	0.89
labour	7.42	7.42	7.42	7.42	3.55	3.55	3.55	3.55
parts	7.42	7.42	7.42	7.42	3.55	3.55	3.55	3.55
- Trailer								
labour	1.65	1.65	1.65	1.65	0.93	0.93	0.93	0.93
parts	1.65	1.65	1.65	1.65	0.93	0.93	0.93	0.93
Driver(s)								
- wages	6.37	6.37	)	)	5.36	5.36	)	)
- allowances	1.51	1.57	)18.97	)25.46	1.13	1.17	) 17.84	)23.21
- overtime	1.21	6.84	)	)	1.23	5.95	)	)
Insurance	1.40	0.73	1.66	0.80	1.05	0.54	1.38	0.64
Overhead	5.91	6.25	6.89	7.19	4.35	4.64	5.3	5.59
Operating component	54.61	59.97	65.73	71.66	35.56	41.10	47.96	52.88
Capital component	14.8	14.8	19.3	19.3	7.4	7.4	9.7	9.7
TOTAL	69.41	74.77	85.03	90.96	42.96	48.50	57.66	62.58

I.3 ROAD MAINTENANCE AND RESEAL COSTS

From the 'Australian Road Survey 1969-74' (specifications for the north west), the costs of maintaining roads per mile have been estimated to depend on N, the number of heavy truck passages per day, as detailed in Table I.3. In our calculations N has been taken as the equivalent number of single bottoms (25 ton) per day at 90% utilisation in the forward direction and empty return.

TABLE I.3 - ANNUAL ROAD MAINTENANCE COSTS

Surface	Cost ($/mile)
Natural	10 + 10N
Earth formed	50 + 20N
Gravel	350 + 11N
Sealed 12 ft	200 + 2.6N
Sealed 20,24 ft	150 + 2.2N

Resealing is carried out at approximately ten- year intervals at the following cost :

width	12ft	20ft	24ft
$/mile	2,460	4,100	4,925

This is minimal for roads north of Geraldton - Meekatharra.

I.3.1 Road Upgrading - Cost and Benefits

A table of construction costs for improving all road links in the north west was provided by the Main Roads Department and included marginal costs of formation, pavement, bridge construction and final sealing to 20 ft and 24 ft widths.

The community savings from improvement are in truck costs (see Table I.2), road maintenance, accident reduction, and user time savings. Costs to be borne are initial capital cost and resealing.

The truck operation is interesting in that sealing a dirt road actually creates 'excess' capacity because greater annual truck mileage can be achieved on bitumen. If a road link under consideration were treated in isolation the normally continuous influx of capital to replace worn vehicles could cease for a period of time, according to the following reasoning.

Assuming static demand, N Ld/2 is average 'ton-miles' of truck available at changeover time, where

N = No. of trucks
Ld = Life of truck in ton-miles on dirt.

At the change, average life is N Lb/2 (Lb = life on bitumen in ton-miles)
Then excess capacity is $N \times \frac{(Lb-Ld)}{2}$ ton-miles

This could be used up in (Lb - Ld)/2Tb years where Tb is ton-miles per annum of a truck on bitumen. Td is ton-miles per annum of a truck on dirt.

Initially, only N x Td/Tb trucks need be used to carry the full load on bitumen. If this figure contains only the newest trucks the first will wear out after (1 - Td)Lb/Tb ton miles - this can immediately be replaced by the newest stored truck etc. The number of years before acquisition of the next truck is now :

$$2\left(1 - \frac{Td}{Tb}\right) Lb \times \frac{1}{Tb} \text{ years.}$$

On figures for Td, Tb, Lb, Ld, etc, it appears a gap of about 2 years in investment should be allowed for the steady state transfer from dirt to bitumen on any one road section. This deferment represents a benefit which is to be accounted for in determining whether a road should should be bituminised or not.

I.3.2 Road Improvements - Theory and Timing

Because the imposition of many conditional changes are inimical to the linear programming concept, it was necessary to study the possibility of changes in road surface during the time scale of the study.

The criteria used for changing the road conditions are that the new truck operating and road maintenance costs per mile of the road link plus an annuity made up of capital upgrading and reseal costs discounted at an acceptable rate should be less than the equivalent current truck and road operating costs per year per mile. An allowance must also be made for deferment of truck renewal, as discussed in the previous section.

The following relations are employed:-

Capital cost of bituminising and resealing (Cb) is approximately twice that for upgrading to a gravel surface (Cg). Thus Cg = 0.5Cb. Truck operating costs on gravel (Tg) are midway between those for bitumen (Tb) and dirt (Td). Thus 2Tg = Tb + Td. This relation is discussed in Winfrey and Lago (see above). With the relationships it becomes possible to study the relative merits of upgrading to gravel ...1 and bitumen ...2 at any given volume of traffic.

$$Cg + Mg + Tg \leq Md + Td \quad \ldots 1$$
$$Cb + Mb + Tb \leq Md + Td \quad \ldots 2$$

where C is the capital annuity for g = gravel and b = bitumen, M is the road maintenance cost per mile per year for g, b and d (= dirt), and T is the truck operating cost to carry the year's tonnage over one mile for g, b and d.

If ...1 is justified, the postulated relationships give

$Cb + 2Mg \leq 2Md + 2Td - 2Tg$ and since
Mg is greater than Md (Table I.3) and
$2Tg = Tb + Td$ then
$Cb + Mg \leq Md + Td - Tb$

Now Mb is everywhere less than Mg therefore we can restate ...1, the condition that upgrading to gravel is justified, by

$Cb + Mb \leq Md + Td - Tb$ which, on rearrangement is exactly the condition required to justify bituminising. This precludes gravel improvements from our model.

The model was exercised on all dirt roads actual and envisaged in the study area. Minimum annual tonnages that would justify sealing were calculated; the major results appear in table I.4. From this table and a prior knowledge of the amounts of freight to be moved along the various sections, it is apparent that the only roads needing a seal in the time frame to 1990 would be Meekatharra - Mt Newman and Nanutarra - Port Hedland, both of which are planned to occur before or early in the study period on present indications. No other major road approaches the justification with indicated tonnages available and all are assumed to remain in their present state.

TABLE I.4 - MINIMUM ANNUAL TONNAGES ON CERTAIN ROADLINKS TO SUPPORT SEALING ON ECONOMIC GROUNDS

Link	Link length	Minimum tonnage
	miles	'000 tons
Tom Price - Wittenoom	67	103
Wittenoom - Mt Newman	113	71
Roebourne - Wittenoom	163	77
Wittenoom - Port Hedland	171	94
Nanutarra - Tom Price	179	112
Port Hedland - Mt Newman	221	107
Mt Newman - Meekatharra	311	67
Port Hedland - Goldsworthy	43	139
Goldsworthy - Broome	322	75

RAIL TRANSPORT

J.1 COST DATA

After discussions with WAGR and agreement on the feasibility of a set of five alternative rail options, details of capital and operating costs for the five alternative upgrading and new rail proposals were provided by WAGR. Costs of these alternatives are summarised in Tables J.1 to J.5.

WAGR pricing practice is, in general, to use the same rates for like commodities over given distances throughout the whole State. But where there is strong competition from other modes, as in seeking freight forwarders' business to the Pilbara and Kimberley, special contract rates may be struck using incremental costing as a basis.

Consistent with the resource cost approach adopted in this report, incremental railway costs (corresponding to the postulated capacity of the rail link under consideration) were calculated as a linear function of tonnage flow along each link. The adjustments made to both the capital and incremental cost components provided by WAGR are detailed later in this Annex. For convenience of analysis, the WAGR upgrading and construction alternatives were rearranged into an equal number of self-sufficient and internally consistent rail options. Tables J.1 to J.5 show the capital expenditures for the WAGR alternatives. Table J.6 summarises how WAGR alternatives were arranged into BTE rail options. The timing and magnitude of the capital investment following from the BTE rail options were then calculated directly from the WAGR data.

In order to reduce the amount of calculation, it was agreed that WAGR should make the following assumptions concerning loading of wagons:

TABLE J.1 - CAPITAL EXPENDITURE FOR WAGR ALTERNATIVE 1

Expenditure	Year	Without project		1A - 250,000 tons p.a.		1B - 500,000 tons p.a.	
		to Geraldton	to Meekatharra	Via MR to Geraldton 145,000 tons p.a.	Via NR to Meekatharra 105,000 tons p.a.	Via MR to Geraldton 290,000 tons p.a.	Via NR to Meekatharra 210,000 tons p.a.
Rolling stock		$'000	$'000	$'000	$'000	$'000	$'000
- new	1975	-	-	1,136.0	1,572.0	3,271.0	4,689.0
- replacement for current capacity	1980	-	-	700.0	350.0	700.0	350.0
- replacement for current capacity	1985	-	-	245.0	353.0	245.0	353.0
Total rolling stock		-	-	2,081.0	2,275.0	4,216.0	5,392.0
Way and works (a)	1975	170.0	4,200.0	340.0	5,830.0	874.0	6,146.0
	1976	170.0	4,200.0	-	4,200.0	-	4,200.0
	1977	400.0	2,300.0	400.0	1,820.0	400.0	2,050.0
	1979	-	-	-	1,000.0	100.0	1,000.0
	1980	-	1,000.0	100.0	830.0	-	830.0
	1981	-	830.0	-	-	-	-
	1982	100.0	-	-	-	300.0	-
	1984	-	-	300.0	-	-	-
	1985	-	-	-	-	-	550.0
	1986	-	-	-	-	-	500.0
	1987	300.0	-	-	-	-	-
	1988	-	-	-	550.0	-	-
	1989	-	-	-	500.0	-	-
Total way and works		1,140.0	12,530.0	1,140.0	14,730.0	1,674.0	15,276.0
TOTAL		1,140.0	12,530.0	3,221.0	17.005.0	5,890.0	20,688.0

(a) Way and works capital costs also include an addition on sleeper renewals of $30,000 p.a. on the MR and $50,200 p.a. on the NR for the 500,000 ton project.

NOTE: In this table, project costs have not been distributed over the construction periods.

TABLE J.2 - CAPITAL EXPENDITURE FOR WAGR ALTERNATIVE 2

Expenditure	Year	2A - 500,000 tons		2B - 750,000 tons	
		Via MR to Geraldton 290,000 tons p.a.	Via NR to Meekatharra 210,000 tons p.a.	Via MR to Geraldton 435,000 tons p.a.	Via NR to Meekatharra 315,000 tons p.a.
		$'000	$'000	$'000	$'000
Rolling stock					
- new	1975	3,514.0	5,496.0	5,319.0	8,227.0
- replacement for current capacity	1985	238.0	360.0	238.0	360.0
Total rolling stock		3,752.0	5,856.0	5,557.0	8,587.0
Way and works (a)	1975	11,500.0	8,125.0	11,700.0	8,125.0
	1976	-	3,125.0	-	3,900.0
	1977	-	1,760.0	-	1,750.0
	1978	-	-	-	-
	1982	-	-	-	-
	1987	-	-	-	-
Total way and works		11,500.0	13,775.0	11,700.0	13,775.0
TOTAL		15,252.0	19,631.0	17,257.0	22,362.0

(a) Way and works capital costs also include an addition for sleeper renewals of $30,000 p.a. on the MR and $50,200 on the Mullewa-Meekatharra line, for both tonnage levels.

NOTE: In this table, project costs have not been distributed over the construction periods.

TABLE J.3 - CAPITAL EXPENDITURE FOR WAGR ALTERNATIVE 3

Expenditure	Year	3A - 250,000 tons			3B - 500,000 tons			3C - 750,000 tons		
		To Geraldton 50,000 tons	To Newman 20,000 tons	To Port Hedland 18,000 tons	To Geraldton 75,000 tons	To Newman 40,000 tons	To Port Hedland 385,000 tons	To Geraldton 100,000 tons	To Newman 60,000 tons	To Port Hedland 590,000 tons
		$'000	$'000	$'000	$'000	$'000	$'000	$'000	$'000	$'000
Rolling stock										
- new	1975	786.0	588.0	6,771.0	1,099.0	1,260.0	13,426.0	1,398.0	1,824.0	20,346.0
- replacements	1985	77.0	57.0	658.0	67.0	77.0	817.0	66.0	85.0	954.0
Total rolling stock		863.0	645.0	7,429.0	1,166.0	1,337.0	14,243.0	1,464.0	1,910.0	21,300.0
		(Mullewa-Geraldton)	(Kewdale-Mullewa)	(Mullewa-Port Hedland)	(Mullewa-Geraldton)	(Kewdale-Mullewa)	(Mullewa-Port Hedland)	(Mullewa-Geraldton)	Kewdale-Mullewa)	(Mullewa-Port Hedland)
Way and works (a)	1975	100.0		37,025.0	100.0	200.0	37,095.0	100.0	400.0	37,315.0
	1976						3,900.0			3,900.0
	1977						2,000.0		2,390.0	2,000.0
	1978					2,390.0				
	1979		2,390.0							
	1980								1,450.0	
	1981									
	1982					1,450.0				
	1984									
	1986		1,450.0						5,820.0	
	1987					5,820.0				
Total way and works		100.0	3,840.0	42,925.0	100.0	9,860.0	42,995.0	100.0	10,060.0	43,215.0
TOTAL		953.0	4,485.0	50,354.0	1,266.0	11,197.0	57,238.0	1,564.0	11,970.0	64,515.0

(a) Way and works capital costs also include an addition for sleeper renewals of $23,000 p.a. on Kewdale-Mullewa and $27,000 p.a. on Mullewa-Meekatharra, at all tonnage levels.

NOTE: In this table, project costs have not been distributed over the construction periods.

TABLE J.4 - CAPITAL EXPENDITURE FOR WAGR ALTERNATIVE 4

Expenditure	Year	4A - 250,000 tons			4B - 500,000 tons			4C - 750,000 tons		
		To Geraldton 50,000 tons	To Mt Newman 20,000 tons	To Port Hedland 180,000 tons	To Geraldton 75,000 tons	To Mt Newman 40,000 tons	To Port Hedland 385,000 tons	To Geraldton 100,000 tons	To Mt Newman 60,000 tons	To Port Hedland 590,000 tons
		$'000	$'000	$'000	$'000	$'000	$'000	$'000	$'000	$'000
Rolling stock										
- new	1975	653.0	573.0	6,103.0	1,051.0	1,024.0	11,397.0	1,415.0	1,473.0	16,759.0
- replacements	1985	70.0	62.0	660.0	72.0	70.0	784.0	76.0	79.0	903.0
Total rolling stock		723.0	635.0	6,763.0	1,123.0	1,094.0	12,181.0	1,491.0	1,552.0	17,662.0
		(Kewdale-Geraldton)		(Geraldton-Port Hedland)	Kewdale-Geraldton)		(Geraldton-Port Hedland)	(Kewdale-Geraldton)		(Geraldton-Port Hedland)
Way and works (a)	1975	10,580.0		71,345.0	11,050		71,345.0	11,250.0		71,345.0
	1976									
	1977									
	1978									
	1982									
	1987									
Total way and works		10,850.0		71,345.0	11,050.0		71,345.0	11,250.0		71,345.0
TOTAL		11,573.0	635.0	78,108.0	12,173.0	1,094.0	83,526.0	12,741.0	1,552.0	89,007.0

(a) Avoidable way and works costs (capital) of $113,000 per annum for sleeper renewals on Mullewa-Meekatharra line also taken into account in costing.

NOTES: Credit has been allowed in the costing for avoidable track costs arising from the closure of the Mullewa - Meekatharra line but as an expedient it has been assumed that other financial effects of the closure of this line would cancel out. Capital costs of the connection from Weld Range to Meekatharra are all attributed to North West Traffic. Project costs have not been distributed over the construction periods in this table.

TABLE J.5 - CAPITAL EXPENDITURE FOR WAGR ALTERNATIVE 5

Expenditure	Year	5A - 500,000 tons			5B - 750,000 tons		
		To Geraldton 75,000 tons	To Mt Newman 40,000 tons	To Port Hedland 385,000 tons	To Geraldton 100,000 tons	To Mt Newman 60,000 tons	To Port Hedland 590,000 tons
		$'000	$'000	$'000	$'000	$'000	$'000
Rolling stock							
- new	1975		9,231.0			13,014.0	
- replacements	1985		213.0			293.0	
- replacements	Var.		3,346.0 Cr			3,346.0 Cr	
Total rolling stock			6,346.0			9,961.0	
		Kewdale-Geraldton		Geraldton-Port Hedland	Kewdale-Geraldton		Geraldton-Port Hedland
Way and works (a)	1975	25,700.0		71,365.0	25,900.0		71,365.0
	1976						
	1977						
	1978						
	1982						
	1987						
Total way and works		25,700.0		71,365.0	25,900.0		71,365.0
TOTAL		25,700.0	6,098.0	71,365.0	25,900.0	9,961.0	71,365.0

(a) Capital costs for sleeper renewals i.e. $113,000 p.a. avoidable with closure of Meekatharra-Mullewa line, and $30,000 p.a. to 1990 decrease and $62,000 p.a. increase from 1990 on Millendon - Utakarra section, also taken into account in costing.

NOTE: The rolling stock capital expenditure credits above are for replacements of existing narrow gauge rolling stock which were assumed to be avoidable at an average time of 1985. In this table, project costs have not been distributed over the construction periods.

TABLE J.6 - RELATIONSHIP BETWEEN WAGR RAIL ALTERNATIVES AND BTE RAIL OPTIONS

BTE RAIL OPTIONS	A1	A2	B1	B2	C1	C2	C3	D1	D2	D3	E1	E2
TONNAGE LEVEL	250,000	500,000	500,000	750,000	250,000	500,000	750,000	250,000	500,000	750,000	500,000	750,000
ADDITIONAL TRAIN LOADS PER WEEK (TONS GROSS) FOR PILBARA	5x900 (MR) 3x850 (K-Mu) 2x1120 (Mu-M)	10x990 (MR) 6x850 (K-Mu) 5x1120 (Mu-M)	2x600 13x1070 (G via MR) 14x1500 (M via MR)	2x600 21x1070 (G via MR) 13x780 (G-Mu) 8x1150 (Mu-M)	8x1070 (K-Mu) 4x1500 (Mu-M) 3x3300 (M-Mt N)	15x1070 (K-Mu) 3x1070 (Mu-G) 10x1500 (Mu-M) 6x3300 (M-Mt N)	22x1070 (K-Mu) 3x1070 (Mu-G) 15x1500 (Mu-M) 6x6600 (M-Mt N)	5x1070 (K-G) 2x600 (K-G) 5x1950 (G-MT N)	14x1070 (K-G) 2x600 (K-G) 6x1950 (G-Mt N)	21x1070 (K-G) 2x600 (K-G) 5x4920 (G-Mt N) 1x2460 (G-Mt N)	6x2080 (K-Mt N)	6x4200 (K-Mt N)
WITHOUT PROJECT (SUBTRACTED)	MR/NR (1)	MR/NR (1)	MR/MR (2)	MR/MR (2)	NR/Mu-PH (3)	NR/Mu-PH (3)	NR/Mu-PH (3)	MR/Mu-PH (2, 3)	MR/Mu-PH (2, 3)	MR/Mu-PH (2, 3)	MR/Mu-PH (2, 3)	MR/Mu-PH (2, 3)
RE-RAIL	MR/NR (1A)	MR/NR (1B)	MR/MR (2A)	MR/MR (2B)	NR/Mu-PH (3A)	NR/Mu-PH (3B)	NR/Mu-PH (3C)	K-G (4A)	K-G (4B)	K-G (4C)	-	-
ROLLING STOCK	MR/NR (1A)	MR/NR (1B)	MR/MR (2A)	MR/MR (2B)	Mu-G/NR/Mu-PH (3A)	Mu-G/NR/MU-PH (3B)	Mu-G/NR/Mu-PH (3C)	K-G (4A)	K-G (4B)	K-G (4C)	K-PH (5A)	K-PH (5B)
TERMINAL WORKS	NR (1A)	MR/NR (1B)	MR/MR (2A)	MR/MR (2B)	G/PH (3A)	G/PH (3B)	G/Mt N/PH (3C)	G-PH (4A)	G-PH (3B,4B)	G-PH (3C,4C)	G-Mt N/ G-PH (4B,5A)	G-Mt N/ G-PH (4C,5B)
NEW TRACK	-	-	-	-	M-Mt N (3A)	M-Mt N (3A)	M-Mt N (3A)	G-Mt N/ Mt N-PH (3A,4A)	G-Mt N/ Mt N-PH (3B,4B)	G-Mt N/ Mt N-PH (3C,4C)	K-G/G-Mt N/ Mt N-PH (3B,4B,5A)	K-G/G-Mt N/ Mt N-PH (3C,4B,5B)
ROLLING STOCK FOR NEW TRACK	-	-	-	-	K-Mt N/ K-PH (3A)	K-Mt N/ K-PH (3B)	K-Mt N/ K-PH (3C)	K-Mt N/ K-PH (3A,4A)	K-Mt N/ K-PH (3B,4B)	K-Mt N/ K-PH (3C,4C)	K-G/K-Mt N/ K-PH (3B,4B,5A)	K-G/Y-Mt N/ K-PH (3C,4C,5B)

NOTES: (1) Figures in brackets refer to WAGR alternatives. (2) BTE options E1 and E2 contain credits for narrow gauge rolling stock. (3) The following abbreviations have been used:-

MR Midlands Railway G Geraldton M Meekatharra Mu Mullewa
NR Northern Railway K Kewdale Mt N Mt Newman PH Port Hedland

- forwarding agents would make up wagon loads
- a negligible proportion of freight would be handled as less than wagon loads
- bogie wagons would be used
- average loads on narrow gauge would be 26 tons per wagon and on standard gauge, 40 tons.

J.2 INCREMENTAL RESOURCE COSTS

The annual incremental costs provided by WAGR were transformed into incremental resource costs using the following formula:

$$MC\,1 = \frac{TC\,1}{1.035} + 0.843\,RS + 0.968\,S + \frac{SH}{1.035} + 0.978W + 0.950V$$

where

MC1	=	incremental resource cost on WAGR track
TC1	=	train crews (WAGR)
RS	=	rolling stock (fuel and maintenance)
S	=	station (handling, clerical etc.)
SH	=	shunting and marshalling
W	=	way and works maintenance
V	=	variable overheads.

These adjustments correspond to removal of taxes from the various components, consistent with the approach adopted in ships and road costing.

For those routes using the Mt Newman to Port Hedland link, there were additional charges. In these cases the following equation was used to determine the incremental resource cost for both WAGR and mining company track (MC2):

$$MC2 = MC1 + 0.80\ C$$

where C is an estimate of the charge made by the mining company on WAGR for the use of the Mt Newman to Port Hedland line.

The incremental operating cost for each route section for a particular freight level was then divided by the specified tonnage carried for that route section to obtain a resource cost per ton. This was the incremental cost used in the linear programming procedure described in Annex K.

J.3 CAPITAL COSTS

The lives of the various classes of equipment making up a capital investment were assesed by WAGR as:

- rerailing - 30 years
- new track - 40 years
- terminal works - 30 years
- rolling stock - 25 years

The costs of building new track were distributed in time so that they represented a feasible expenditure profile : 10% was allocated to the first year of the particular project, 10% to the second year, 60% to the third year and 20% to the fourth and final year. The aggregated rail capital injections for projects starting in 1975 are shown in Table J.7. Similar calculations were made for 1976, 1977 and 1978 starting dates.

In the options where more than one new rail link is required (D1, D2, D3, E1, E2), the capital expenditure was staggered so that the first year's expenditure on one major link coincides with the final year's expenditure on the preceding link.

TABLE J.7 - AGGREGATED ADDITIONAL RAIL CAPITAL INJECTIONS (ABSOLUTE) FOR PROJECTS STARTING IN 1975

($ Million)

Year of Expend	A1	A2	B1	B2	C1	C2	C3	D1	D2	D3	E1	E2
1974	.000	.000	.000	.000	3.746	4.479	5.227	3.936	4.669	5.417	4.669	5.417
1975	4.508	10.610	22.165	26.901	14.916	23.559	32.510	13.491	14.825	16.175	12.175	16.906
1976	-.170	-.170	-.170	-.170	22.476	26.874	31.362	19.546	23.944	28.432	23.944	28.432
1977	-.280	-.500	-.450	-.450	7.492	8.958	12.844	10.052	12.092	14.169	12.092	14.169
1978	-.200	-.100	-.200	-.200	.000	2.390	.000	4.180	4.754	5.335	4.754	5.335
1979	1.000	1.000	.000	.000	2.390	.000	.000	26.280	29.724	33.210	29.724	33.210
1980	.980	.880	.000	.000	-1.000	-1.000	.450	8.760	9.908	11.070	13.046	14.587
1981	-.830	-.830	.000	.000	-.830	-.830	-.830	.000	.000	.000	3.138	3.517
1982	-.100	.200	-.100	-.100	.000	1.450	.000	-.100	1.100	-.100	24.728	27.001
1983	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	6.276	7.034
1984	.300	.000	.000	.000	.715	.894	1.040	.715	.894	1.040	.894	1.040
1985	.598	1.148	.598	.598	.792	.961	1.106	.070	.072	.076	.213	.293
1986	.000	.500	.000	.000	1.450	.000	5.820	.000	.000	.000	.000	.000
1987	-.300	-.300	-.300	-.300	.000	5.820	.000	.000	.000	.000	.000	.000
1988	.550	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
1989	.500	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
1990	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.213	.293

NOTE: Capital injections are additional to those involved in the 'without project' case; negatives (-) indicate expenditure in the 'without project' case with no expenditure for the relevant rail option.

J.3.1 Capital costs of new rolling stock for new track

The expenditure on new rolling stock for the new rail links was staggered in the same way as for other capital classes (Table J.8). The capital costs of new rolling stock in 1975 and replacements in 1985 for options C1, C2, C3, D1, D2 and D3 are, in each case, the sum of the capital costs given for new rolling stock required for Perth to Mt Newman and Perth to Port Hedland.

The capital cost of new rolling stock in 1975 and replacements in 1985 for options E1 and E2 are taken directly from the information sheets provided by WAGR.

J.3.2 Residual value of rail capital injections

To make due allowance for asset lives extending beyond the study period, the capital flows were treated as follows. The particular asset under consideration was assumed to be maintained in perpetuity by replacing it each time its life ended. This generates a certain cash flow. A second cash flow was postulated as arising from an initial renewal of the asset in the year following the last year of the study period, followed by a corresponding set of cash flows arising from maintenance in perpetuity. The difference between the discounted values of these two cash flows is the residual value of the asset at the end of the study period. The residual value is thus determined from the following formulae:

$$PV = PV1 - PV2$$

where PV = Present value (1 Jan 1972) of the residual value of the asset at the end of 1990.

and PV1 = Present value of the capital stream if the asset is replaced at the termination of its economic life cycle.

PV2 = Present value of the capital stream if the asset is replaced immediately following the end of the evaluation period (1990, the 16th year of the study

TABLE J.8 - DISTRIBUTION OF NEW ROLLING STOCK COSTS FOR NEW TRACK

Year	Rail Options							
	3A	3B	3C	4A	4B	4C	5A	5B
1974	x_1	x_2	x_3	x_1	x_2	x_3	x_2	x_3
1975	x_1	x_2	x_3	x_1	x_2	x_3	x_2	x_3
1976	$6x_1$	$6x_2$	$6x_3$	$6x_1$	$6x_2$	$6x_3$	$6x_2$	$6x_3$
1977	$2x_1$	$2x_2$	$2x_3$	$2x_1+y_1$	$2x_2+y_2$	$2x_3+y_3$	$2x_2+y_2$	$2x_3+y_3$
1978				y_1	y_2	y_3	y_2	y_3
1979				$6y_1$	$6y_2$	$6y_3$	$6y_2$	$6y_3$
1980				$2y_1$	$2y_2$	$2y_3$	$2y_2+z_2$	$2y_3+z_3$
1981							z_2	z_3
1982							$6z_2$	$6z_3$
1983							$2z_2$	$2z_3$
1984	a_1	a_2	a_3	a_1	a_2	a_3	a_2	a_3
1985								
1986								
1987				b_1	b_2	b_3	b_2	b_3
1988								
1989								
1990							c_2	c_3

NOTE: The following symbols are used -

x_1, x_2, x_3, are each 10% of the total new rolling stock costs for the alternatives 3A, 3B, 3C, respectively, Meekatharra to Mt Newman.

y_1, y_2, y_3, are each 10% of the total new rolling stock costs for the alternatives 4A, 4B, 4C, respectively, Mt Newman to Port Hedland.

z_2, z_3, are each 10% of the total new rolling stock costs for the alternatives 5A, 5B, respectively, Perth to Geraldton.

a_i, b_i, c_i, are rolling stock replacement costs.

period) and then at the termination of its economic life cycle.

$$PV1 = A \left[\frac{(1+i)^{n-m}}{(1+i)^{n} - 1} \right]$$

$$PV2 = A \left[\frac{(1+i)^{n-k}}{(1+i)^{n} - 1} \right]$$

Where A = value of the capital injection
n = life of the asset pertaining to the capital injection
m = year of initial investment under strategy 1 (1973 = 1)
i = discount rate
k = 18, time from base year (1972) to end of study period (1990).

The present values of rail capital assets, net of the discounted residual values, were calculated for four years of initial investment, namely 1975, 1976, 1977 and 1978. These figures are in Table J.9.

TABLE J.9 - PRESENT VALUE OF RAIL CAPITAL ASSETS

($ million)

Discount rate	Project Commenc	A1	A2	B1	B2	C1	C2	C3	D1	D2	D3	E1	E2
5%	1975	3.110	7.185	13.095	16.062	26.470	36.648	46.686	37.932	45.072	52.301	53.055	63.558
	1976	2.108	5.813	11.178	13.905	23.323	23.429	41.542	33.465	39.873	46.361	46.630	56.031
	1977	1.165	4.507	9.356	11.851	20.326	28.412	36.643	29.211	34.921	40.705	40.510	48.863
	1978	.284	3.263	7.680	9.894	17.472	24.585	31.977	25.159	30.206	35.317	34.682	42.036
Discount rate	**Project Commenc**	**A1**	**A2**	**B1**	**B2**	**C1**	**C2**	**C3**	**D1**	**D2**	**D3**	**E1**	**E2**
7%	1975	3.110	7.201	13.277	16.291	27.283	37.397	47.424	39.010	46.018	53.114	53.620	63.915
	1976	2.000	5.675	11.143	13.847	23.702	32.656	41.649	33.964	40.182	46.479	46.538	55.652
	1977	.974	4.249	9.148	11.563	20.356	28.225	36.251	29.248	34.728	40.278	39.920	47.929
	1978	.061	2.916	7.284	9.429	17.229	24.084	31.207	24.841	29.631	34.483	33.733	40.712
Discount rate	**Project Commenc**	**A1**	**A2**	**B1**	**B2**	**C1**	**C2**	**C3**	**D1**	**D2**	**D3**	**E1**	**E2**
10%	1975	3.049	7.087	13.296	16.272	27.528	37.369	47.197	38.955	45.646	52.422	52.367	62.183
	1976	1.800	5.358	10.817	13.438	23.383	31.948	40.595	33.207	39.043	44.943	44.553	53.092
	1977	.674	3.786	8.663	10.861	19.615	27.020	34.593	27.982	33.031	38.145	37.145	44.827
	1978	.340	2.357	6.514	8.518	16.189	22.539	29.137	23.232	27.571	31.965	30.993	37.313

NOTE: Present values are net of residual values.

ANNEX K

THE LINEAR PROGRAM

When the costs of various transport options and strategies have been identified, the problem of finding the least cost option may be formally represented as an example of the 'warehouse allocation' linear program. The solution to this type of problem has been subject to much theorising and currently the most readily available computer solution is by the Simplex algorithm. Some insight on this method will be obtained from 'Principles of Operations Research' Wagner, 1969 (paras. 3.3, 3.4, 4.4, 6.4, 7.2, 7.3, 13.2, 13.3, 13.5).

K.1 THE PROBLEM

In general, the 'warehouse problem' has supply centres and demand centres for various products. The objective is to minimise delivery costs by judicious selection of supply centres and transport links. Further complications may be added by including fixed set-up costs for possible new warehouses. This takes the problem into the realms of mixed integer programming, i.e. the set-up cost is either wholly included or wholly excluded.

The 'warehouses' are taken as Perth and Adelaide, and the supply points are various nodes (towns and ports) in the north west as described in the text. Transportation of two products (described as 'development' and 'logistic') is provided by road, rail and sea links which each have an operating cost per ton of product carried. The various rail options are mutually exclusive (see Annex J). A rail option is an investment of capital, discounted to 1972, which provides a prescribed level of service (cost and capacity) over the study period. This gives the mixed integer component of the linear program.

The road options (upgrading and re-routing) have been dealt with in Annex I.

The sea component has been reduced, by the ship study (Annex F), to one option for each of seven share proportions of total cargo assumed captive to sea. A continuous function of ship costs over the whole spectrum of cargo loads would have allowed for neater solution but, because each quantity of cargo required new scheduling arrangements, this refinement was impracticable.

K.2 REFINEMENTS TO THE PROBLEM

An additional complication was the annual capacity on each rail link, which gave restrictions over each of the sixteen years of the study. Running costs were discounted at three rates. Another refinement was the provision for a rail link from Mt Newman to Dampier if and only if a standard gauge upgrading was available to Mt Newman.

The final aim was to find the best rail options, given various proportions of total freight to land, but initially the linear program was solved by allowing any fractional combination of rail options. The fractions were constrained such that their sum was equal to unity, e.g. the 'best' rail option initially computed might give 0.5 of a standard gauge upgrading plus 0.5 of the status quo. This method gives a lower bound to the cost of the final solution and an indicator as to the size of rail option that will ultimately prove to be the most effective but, of course, split options such as this are not physically meaningful. The logic of changing from a split option to the best single option is transparent to the observer but imposes considerable difficulty on the computer.

A continuation into this phase is known as a mixed integer program (some variables are constrained to integer values, which in this case means one option out of 48 may be selected but then temporarily no other is considered). One technique for solving this type of problem is known as the 'branch and bound' method. This involves putting, sequentially, each of the relevant variables to an allowable integer value, minimising the problem at each step (or node as it is called) and keeping a tally of the results. Along this particular branch a solution (in which all of the variables are integral) is finally reached, to give a bound to the problem. This bound is feasible but not proven to be the best. The nodes are then retraced testing to see if by putting the variables to other possible integers a reduction of the bound is possible. In this way each node is tested until either :

- a full integer solution is reached which is better than the old bound and this becomes the new bound; or

- any further exploration can only result in a solution which is infeasible or worse than the current bound.

Finally, because the mixed integer solution only pinpoints the absolute minimum and to provide greater scope for analysis, programming was carried out individually on those options indicated as 'possibles' to arrive at a table of comparisons around the least cost option. This entailed solving the allocation model with selected options only being forced into the solution (as opposed to the mixed integer program where the computer is allowed to choose which options to examine in detail).

K.3 DETAILS OF THE PROBLEM FORMULATION

Forty-eight rail options were available, involving five possible alternative configurations of narrow and standard gauge upgrading. Each configuration had two or three orders of magnitude and four project start years. Cargo was split into logistic and development. Seven levels of total freight share to the land modes were tested over the 16 study years at three different discount rates. The basic linear criteria used were as follows:-

(a) The costs over 16 years to be MINIMISED were:
Σ(proportion of any rail option selected x discounted capital cost of this option)

+

Σ(tons allocated to rail option x discounted cost per ton)

+

Σ(tonnage allocated to each road section x discounted cost per ton)

(b) One and only one real or split option to be chosen, i.e. Σ(proportion of any rail option selected) = 1

(c) Each rail link had a capacity restraint; (proportion of any rail option selected x capacity of the complete rail option) $\geq$ tonnage allocated to this option in any year.

(d) The demands must be met at each node, e.g. for each year, tonnage allocated to rail options to Mt Newman and tonnage allocated to road links to Mt Newman = demand for freight at Mt Newman + tonnage allocated to rail options to Pt Hedland + tonnage allocated to road options to Pt Hedland.

(e) The basic requirement of the linear program, all tonnages and rail options $\geq$ 0.

K.4 IMPLEMENTATION OF THE PROBLEM SOLUTION

The problem as outlined above was solved on the CDC 6600 computer with the matrix generator package MAGEN and the OPHELIE linear programming package.

More formally, the linear program may be expressed algebraically as :

MINIMISE the objective function :

$$\sum_{\substack{yw\\d}} R_d^{yw} \times \$_R \quad + \sum_{\substack{yw\\d\\n\\da\\l}} T_{d,da,l}^{yw,n} \times \$_T \times F_{da} \quad + \sum_{\substack{pp\\da\\l}} T_{da,l}^{pp} \times \$_T \times F_{da} \quad + \quad SH^{1-K}$$

Subject to :

$$\sum_{\substack{yw\\d}} R_d^{yw} \qquad = 1 \quad \text{Unique rail}$$

$$R_d^{yw} \times C_{d,da}^{yw,n} - \sum_{l} T_{d,da,l}^{yw,n} \qquad \geq 0 \quad \forall yw,n,d,da$$

$$\pm \sum_{\substack{E\,(yw)\\n\\d}} T_{d,da,l}^{yw,n} \quad \pm \sum_{E\,(pp)} T_{da,l}^{pp} \qquad \geq E \times K \quad \forall E,da,l$$

$$\sum_{\substack{yw\\d}} T_{d,da,l}^{yw,n} \quad - \quad T_{da,l}^{pp} \qquad \geq 0 \quad \forall da,l \text{ when } n = 1,\ pp = 1$$

$$R_d^{yw}, \quad T_{d,da,l}^{yw,n}, \quad T_{da,l}^{pp} \qquad \geq 0 \quad \forall pp,yw,n,d,da,l$$

$$R_d^{yw} \qquad \leq 1 \quad \forall yw,a$$

where the sets :

- (T) are tonnages of freight commodity groups
- (R) are proportions of rail options
- (C) are capacities of rail links
- (E) are demands at population centres
- (K) is proportion of freight to land modes
- (SH) are present values of ship capital and operating costs
- ($) are incremental resource costs per ton for road or rail link and present values of rail capital injections
- (F) are discount factors for each discount rate.

the symbols :

- $\sum$ is summation
- $\forall$ is 'for all'.

the subscripts

- yw are rail options to Mt Newman with links n = 1 for Port Hedland
- wy are rail options to Meekatharra only with links g (not shown)
- pp are road links and pp = 1 for Fortescue Valley rail link
- d is one of four project start years
- da are study years 1975 to 1990
- l is commodity group logistics or development.

The Simplex tableau, as developed by the matrix generator, for solution using the Ophelie package is as follows :

Row names for the tableau	Number of columns in tableau: Rail capital		Network links: Rail		Network links: Road	Sea	RHS	Number of rows in tableau
	16	32	3,072	1,024	384	1	9	
	yw,d	wy,d	yw,n,d, da,d,l	wy,g, da,d,l	pp,da,l	SH		
Rail option	1	1					=1	1
yw,n,d, da	C		-1				=0	1,536
wy,g,d, da		C		-1			=0	512
PORT,da			+1 (n=1)		-1 (pp=1)		=0	16
E,da,l			±1	±1	±1		=ExK	288
Sea option						1	$=SH^{1-K}$	1
Objective (F)	Present values of rail capital		Costs per ton		Costs per ton	PV's capital and op'ng		3

NOTE: It is implicit in the linear program that the 4,538 column vectors are also positive.