Consumption of Transport Energy in Australia 1975/76

Occasional Paper

This Paper represents the second study into the estimation of the consumption of energy by Australian transport. The results of the first study were published in Occasional Paper 4 which was based on data for the year s 1970-71. The present paper covers the years 1975-76. Many problems concerning data and assumptions became obvious during preparation of the original paper. These were reflected in the present study by a considerable effort to improve the quality of the estimates and to underpin the supporting assumptions. As a result the present paper is considered to contain more accurate estimates than those in the original paper.

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Consumption of Transport Energy in Australia 1975-76

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AUSTRALIAN GOVERNMENT PUBLISHING SERVICE
CANBERRA 1980

ISBN 0 642 05819 9

Printed by C. J. THOMPSON, Commonwealth Government Printer, Canberra

FOREWORD

This paper represents the second essay by the Bureau of Transport Economics into the estimation of the consumption of energy by Australian transport. The results of the first study were published in Occasional Paper 4 which was based on data for the year 1970-71. The present paper covers the year 1975-76.

Many problems concerning data and assumptions became obvious during preparation of the original paper. These were reflected in the present study by a considerable effort to improve the quality of the estimates and to underpin the supporting assumptions. As a result the present paper is considered to contain more accurate estimates than those in the original paper.

The study was carried out by Mr L.C. Lawlor and Mr M.A. Brown of the Planning and Technology Branch. Assistance was provided also by Mr C. Sayers of the same branch.

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November 1980

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SUMMARY

This report examines the non-military transport task performed in Australia during 1975-76 by both domestic and international modes of transport, and presents estimates of the energy used by the various forms of land, sea and air transport. The main points which emerge from the study are as follows.

Domestic passenger task (passenger-kilometres)

The road mode accounted for 90 per cent(1) of the task. Cars and station wagons accounted for 80 per cent, with utilities and panel vans accounting for 5 per cent and buses for 5 per cent also. The task was about equally divided between urban and non-urban areas.

The urban bus task was about the same size as the non-urban bus task. The urban rail task was 2 1/2 times the size of the non urban rail task, while the air task was 3 times the size of the non-urban rail task.

Domestic freight task (tonne-kilometres)

The sea mode accounted for 50 per cent of the task. Rail freight accounted for 30 per cent while road vehicles accounted for the remaining 20 per cent of the task.

Only 7 per cent of the freight task was carried out in urban areas, with the remainder in non-urban areas. The non-urban truck task was twice the size of the urban truck task, and the Government rail task was equal to the non-Government rail task.

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(1) Percentages in this Section have generally been rounded to the nearest 5 per cent.

International transport task (passenger and freight)

The air mode accounted for almost all the passenger task (measured in passenger-kilometres) while the sea mode accounted for almost all the freight task (measured in tonne-kilometres).

The international passenger task was equal to 20 per cent of the passenger task of cars and station wagons. The international freight task was equal to 11 times the total domestic freight task.

Domestic direct transport energy consumption

Road vehicles accounted for 85 per cent of direct transport energy consumed which totalled 613 Petajoules (PJ)[1]. Cars and station wagons accounted for 55 per cent while other road vehicles accounted for 30 per cent. Over 70 per cent of the energy consumed by cars and station wagons was related to travel in urban areas. Two-thirds of road transport energy was consumed in urban areas. Taking all modes into account, 60 per cent of transport energy was consumed in urban areas, and 40 per cent in non-urban areas. Urban and non-urban passenger transport accounted for about one-half and one-quarter of domestic energy consumption respectively. Road freight transport was about equally divided between urban and non-urban areas in terms of energy consumption.

National direct transport energy consumption

Of the total estimated national consumption of 699 PJ, domestic consumption amounted to 90 per cent and fuel uplifted in Australia by international transport accounted for 10 per cent. Road vehicles accounted for 75 per cent of national energy

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(1) 1 Petajoule (PJ) = 10^{15} Joules.

consumption; cars and station wagons accounted for 50 per cent and other road vehicles accounted for 25 per cent. Air and sea modes accounted for 10 per cent each, and the rail mode accounted for the remaining 5 per cent. Oil based fuels accounted for about 99 per cent of national transport energy consumption.

Two-thirds of national direct transport energy consumption related to passenger transport with one-third relating to freight transport. Road passenger transport energy consumption was 3 times the magnitude of that for road freight transport. Rail freight energy consumption was 1 1/2 times the magnitude of rail passenger energy consumption. Non-urban passenger transport energy consumption was equal to non-urban freight transport energy consumption.

Comparison of 1970-71 with 1975-76

Only limited comparison could be made between 1971-72 and 1975-76 due to the lack of certain data and differences in methods of analysis used. The total distance travelled by cars and station wagons increased by 25 per cent, while the proportion of the total distance travelled by road vehicles undertaken by cars and station wagons remained constant at 80 per cent. The passenger task of cars and station wagons also increased by 25 per cent while the proportion of the domestic passenger task accounted for by these vehicles fell slightly to 80 per cent. There was also a 25 per cent increase in the amount of direct energy consumed by cars and station wagons over this period.

The passenger task of domestic airlines increased by 45 per cent in the 5 years to 1975-76. The freight task of Government railways increased by 20 per cent while the freight task of non-Government railways almost doubled.

The proportions of the freight task accounted for by road, rail and sea modes remained unchanged. There was no significant change in the overall energy intensiveness of cars and station wagons over the 5 year period.

Indirect tranport energy consumption (energy other than propulsion energy)

Indirect energy consumption associated with the transport sector was estimated at one quarter of direct energy consumption.

Overall conclusions

The sum of national direct and indirect transport energy consumption was estimated at 859 PJ for the year 1975-76. Of this total, 96 per cent was assessed as being oil based energy.

CHAPTER 1 - INTRODUCTION

STUDY BACKGROUND

In 1975 a consultant study was released by the Bureau of Transport Economics (BTE) which described the non-military transport task and the corresponding energy consumption for Australia as a whole. The study was published in two parts as Occasional Papers 2 and 4[1][2].

Occasional Paper 2 briefly reviewed energy supply and demand issues in Australia and highlighted the fact that there was little detailed information available on the pattern of transport energy consumption. Occasional Paper 4 gave estimates of the Australian non-military transport task and energy consumption for each major mode of transport.

The data base year used in the study was 1970-71. That year was chosen because data for the mode which consumed the greatest amount of transport energy, road transport, were based mainly on the periodical Survey of Motor Vehicle Usage[3], the most recent at that time being for the twelve months ended September 1971.

Since these Occasional Papers were released there has been a significant growth of interest in energy matters. There is an increasing concern over the future cost and availability of

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(1) Clark, N. and Associates, *Occasional Paper 2: Transport and Energy in Australia Part 1 - Review*, Bureau of Transport Economics, Canberra 1975.
(2) Clark, N. and Associates, *Occasional Paper 4: Transport and Energy in Australia Part 2 - Consumption by Categories*, Bureau of Transport Economics, Canberra 1975.
(3) Commonwealth Bureau of Census and Statistics, *Survey of Motor Vehicle Usage, 12 months ended 30 September 1971*, Canberra, 1973. Ref 14.4.

liquid fuel energy in Australia and this paper is intended to assist in assessing the implications of alternative energy policy options.

Occasional Paper 4 appears to be the only currently available document which provides an analysis of the task performed and fuel energy consumed by all modes of transport for Australia as a whole. The principal aim of the present study was to update the transport task and energy consumption estimates from Occasional Paper 4, and to ensure that the assumptions used to support them were as reasonable as possible given the varying availability and quality of relevant information. The study year chosen is 1975-76, the most recent year for which a sufficient data base is available. In particular it corresponds with the most recent Survey of Motor Vehicle Usage(1) conducted by the Australian Bureau of Statistics (ABS).

Because of differences in the assumptions made and the availability of necessary information, it has proved difficult to make comprehensive comparisons of energy usage between Occasional Paper 4 and this paper. The comparisons which have been made are, however, considered to be reasonably well based.

ACCURACY OF DATA USED

The accuracy of estimates presented in this paper is discussed in qualitative terms where appropriate in the text. The only estimates derived from survey data are those for road vehicles, obtained from the ABS surveys of Motor Vehicle Usage(1) and Bus Fleet Operations(2). Standard errors of sampling accuracy

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(1) Australian Bureau of Statistics; *Survey of Motor Vehicle Usage, 12 months ended 30 June 1976*, Canberra 1978, Ref 9202.0

(2) ABS; *Survey of Bus Fleet Operations, 12 months ended 30 June 1976*, Canberra 1979, Ref 9203.0.

are quoted by ABS for these data and are not quoted in this report. The ABS survey was designed to ensure that the standard errors were acceptably small for the main survey tables. In some of the sub-categories of data, however, the vehicle sample sizes corresponding to some cells in the main survey tables became quite small, with a corresponding increase in standard error. The extent of non-sampling errors associated with the survey data is unknown.

For other modes, the transport task data published are generally obtained directly from returns by transport operators and authorities. Thus sampling errors are not applicable and no comment can be made on the accuracy of the data. Aggregate fuel consumption data by primary fuel type are compiled by Department of National Development[(1)] directly from oil industry returns.

The major sources of error are associated with sub-divisions within data tables, based on assumptions made in this analysis. The likely magnitude of such errors is difficult to assess, but they are discussed in the text where appropriate.

THE APPROACH AND SCOPE OF THE STUDY

Study Approach

The aim of this paper is to describe Australia's non-military transport task and to identify and quantify all energy uses associated with the transport sector for the study year. The major use by far is for vehicle propulsion; this usage is defined as the direct component of total transport energy. This is related as far as possible to the transport task performed.

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(1) Department of National Resources, *Petroleum Statistics Fiscal 1976-77*, Melbourne 1977.

The transport task is expressed in distance (km) travelled by both passenger and freight vehicles. Further, for the passenger task, the numbers of passengers (or passenger journeys) and passenger-km are listed wherever data are available. The freight task is expressed in terms of tonnes carried and net tonne-km achieved.

The overall transport task and the direct energy consumption for both passenger and freight transport are dissected by means of a set of cross tabulations applicable to each transport mode, such as area (e.g. urban and non-urban), and journey purpose (e.g. business and private). For air and sea transport a distinction is drawn between domestic and international operations.

There are many ways in which energy is utilised in the transport sector, other than in the direct consumption of fuel by transport vehicles. The collective sum of these is defined as the <u>indirect</u> component of transport energy. It is indirect in the sense that it cannot be related directly to the level of transport task performed although essential to that performance. It comprises the energy consumed by industrial, commercial and construction activity associated with transport. The principal examples of these energy uses are in vehicle manufacture, maintenance and repair, in the refining of fuels and lubricants, and in the construction of fixed transport facilities such as roads and railway lines.

For the purpose of energy accounting, the distinction between direct and indirect energy is entirely arbitrary. It has developed because it is relatively easy to measure or estimate the direct usage of fuels for vehicle propulsion. It is more difficult to separately determine the extent to which other energy end uses are related to transport, and to measure them with appropriate accuracy.

For this reason, it is generally the case that in published studies of sectoral use of energy, the energy value of transport vehicle fuels consumed is the only form of energy allotted to the transport sector. Industrial and commercial energy uses which relate to the transport sector are contained within energy totals for other sectors. For Australia, these totals are not available in a sufficiently disaggregated form to readily identify the indirect energy consumed by the transport sector. Thus the proportion of Australia's total energy consumption attributable to the transport sector is likely to be larger than is generally reported. Indirect energy consumption is discussed in Chapter 7 of this paper, which discussed the definition and measurement of indirect energy and presents some preliminary estimates of its magnitude.

Scope of Study

Since there is no information publicly available on the Australian military transport task, the military transport task and the corresponding energy consumption have not been taken into consideration in this Study.

It is important to consider energy flows across national boundaries and to decide how to account for them. Apart from examining the energy used by international transport outside Australia for energy intensiveness estimates, the boundaries of this study have been chosen to include only transport energy obtained by end users from within Australia. Since the emphasis of this study is upon energy demand rather than its supply, it is not of primary concern whether fuels have been refined within Australia or imported in refined form, or whether they originate from indigenous or imported feedstocks. This boundary definition corresponds with the definition of energy consumption generally employed in national energy accounts, which is taken as the sum of production, plus imports, minus exports, plus any net change in stocks.

The study deals with national energy consumption which was defined to cover energy consumed by all domestic transport within Australia as well as those amounts of international shipping and aircraft fuel which are uplifted in Australia. This study therefore does not take account of fuels purchased overseas which enter Australia in the bunkers of ships and aircraft.

In this study, energy is accounted for in terms of its consumption by end users during the study year. No attempt is made to evaluate energy costs or to discuss wider issues such as energy demand and supply interaction, energy pricing, demand and price elasticities and future trends.

REPORT STRUCTURE

Chapter 2 provides an overview of Australian energy consumption. Firstly, it discusses Australia's overall use of primary fuels relative to other regions of the world in 1976. Secondly, it examines the transport sector's estimated use of energy in Australia relative to other sectors for the study year 1975-76. A dissection of the usage of primary fuels and electricity by major economic sectors is also provided.

In chapters 3 to 6, the transport task performed and the corresponding direct energy consumption are presented as tabular data for each transport mode. Assumptions made in deriving the tables are explained in the text. To retain clarity in the body of the report, supporting notes and detailed calculations are removed to Appendixes I through IV, corresponding to Chapters 3 through 6 respectively. Appendix V contains further data tables on road vehicles derived from the Survey of Motor Vehicle Usage(1), collected separately to simplify the presentation in Chapter 3.

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(1) ABS, Survey of Motor Vehicle Usage, *op.cit.*

Chapter 7 discusses the definition and measurement of indirect energy and contains some estimates of the magnitude of components of indirect energy.

In Chapter 8, the data presented earlier in the report is summarised and re-assembled to allow a ready comparison of energy consumption across the modes of transport. Observations are made on the need for improved data collection and presentation, and for carrying out further work. The task and operations of major pipelines are not included with the data for other modes and are separately described in Appendix VI.

CHAPTER 2 - ENERGY CONSUMPTION OVERVIEW

INTRODUCTION

This chapter contains a brief statistical review of world and Australian energy consumption as a background to the central theme of this paper, the dissection of energy use by the transport sector in Australia.

Firstly the consumption of primary fuels by world regions is examined and compared with Australia's primary fuel mix for the year 1976. A broad analysis is then undertaken of energy flows in the major sectors of the Australian economy, from primary input to end use. Finally a descriptive account of the use of fuels by the transport sector is given and the measurement of the energy efficiency of transport is discussed.

PRIMARY FUEL CONSUMPTION BY WORLD REGIONS

The demand for primary fuels by major world regions in 1976 is summarised in Table 2.1. Australia's usage of fuels represented about 1 per cent of the world total, compared with USA (27 per cent), Western Europe (20 per cent) and Japan (6 per cent). Thus our major trading partners accounted for over 50 per cent of the world total.

Oil is the dominant energy source, providing almost 45 per cent of the world's energy needs, 56 per cent of energy needs in Western Europe and 71 per cent in Japan. The proportion for Australia, at 46 per cent, was comparable with that for the USA. Both countries have an abundance of coal, with Australia obtaining 39 per cent of its energy from this source, while coal constituted only 19 per cent of the US energy mix. On the other hand, natural gas contributed only 8 per cent of Australia's total, significantly lower than the world average of 18 per cent. Australia's large known reserves of natural gas should lead, however, to considerable expansion of the use of this fuel over

TABLE 2.1 - WORLD PRIMARY FUEL CONSUMPTION, BY SELECTED REGIONS, 1976

(Petajoules-PJ)

Region/Country	Fuel Type					TOTAL
	Petroleum[(a)] Products	Natural Gas	Solid Fuels	Hydro[(b)] Power	Nuclear[(c)] Power	
USA	33 840	21 250	14 420	3 130	2 020	72 660
Canada	3 530	1 810	630	2 150	170	8 300
Latin America	7 670	1 670	2 140	1 480	30	12 980
West Germany	5 730	1 490	3 140	130	230	10 720
United Kingdom	3 770	1 420	2 960	50	310	8 510
France	4 830	760	1 090	510	170	7 360
Italy	4 050	1 030	370	420	40	5 910
All EEC countries	22 040	6 540	8 260	1 110	880	38 830
Western Europe	29 060	6 880	10 710	3 830	1 200	51 680
USSR	15 640	10 390	15 940	1 760	310	44 030
Eastern Europe	3 700	210	10 970	300	30	17 220
China	2 720	210	13 890	280	-	17 100
Japan	10 440	450	2 470	900	390	14 650
SE Asia	3 700	170	2 470	300	-	6 740
Africa	2 230	270	2 400	370	-	5 270
Other countries	4 580	1 500	2 630	580	40	11 290
Australia[(c)]	1 290	240	1 190	50	0	2 770
(per cent)	(46)	(8)	(43)	(2)	(0)	(100)
WORLD	118 460	47 040	79 860	15 130	4 190	264 680
(per cent)	(44)	(18)	(30)	(6)	(2)	(100)

(a) Consumption = Crude Oil production plus imports plus liquid fuels from other sources, less exports plus changes in stocks. Bunkers and petroleum industry use included.
(b) Nuclear power and hydro power for countries other than Australia are at the high (input) factor, i.e. the quantity of fossil fuel which would be required in conventional power stations to generate the same amount of electricity. The hydro power figure for Australia is the generated output.
(c) Average of values for 1975-76 and 1976-77.

Sources: Other than Australia; BP Ltd, *BP Statistical Review of the World Oil Industry 1976*, London, 1977, p.16. Australia; Department of National Development, *End Use Analysis of Primary Fuels Demand, Australia 1973-74 to 1986-87*, Canberra, 1978.

the next decade. The importance of hydro-electric power in Australia is expected to decline, with most of the potential being already developed.

The annual growth rate of world energy consumption averaged 4 per cent over the 10 years to 1976, while the growth in world oil consumption was higher at almost 6 per cent over the same period. There was a slight reduction in total oil consumption due to the 1973 price rises, but this fall was not reflected in overall world primary energy consumption figures.

Some European countries, particularly the UK, did achieve an absolute reduction in oil consumption by measures such as shifting to natural gas and marginally cutting total energy demand. Since 1973 there has been a dramatic rise in natural gas exploitation in many regions.

Statistics are published by the OECD(1), which describe the production and use of energy by its member countries. OECD figures for domestic energy consumption are listed in Table 2.2 for selected countries. Numerically, they do not differ greatly from the BP values shown in Table 2.1, although the definitions employed by each are different. This can be seen by comparing the footnotes to each table. In particular, the OECD data exclude ships' bunkers. A further likely source of difference between the tables is in the factors used to convert volumes or tonnages to energy values. The BP data were expressed in tonnes oil equivalent (toe), and conversion factors listed by BP(2) for each primary fuel were used to derive Table 2.1. Table 2.2 was derived from OECD tables expressed in tonnages, using conversion factors obtained from the OECD(3). For

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(1) OECD, *Energy Statistics, 1974-76*. Paris 1978.
(2) BP Ltd, *BP Statistical Review of the World Oil Industry, 1976*, London, 1977, p.32.
(3) OECD, *Energy Balances for OECD Countries, 1960-1974*, Paris 1976.

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TABLE 2.2 - OECD ESTIMATES OF NATIONAL DOMESTIC ENERGY CONSUMPTION FOR SELECTED COUNTRIES, 1976

(PJ)

Country	Fuel Type					TOTAL
	Petroleum[(a)] Products	Natural Gas	Solid Fuels	Hydro[(b)] Power	Nuclear[(c)] Power	
United States	33 820	21 530	14 470	1 040	730	71 590
West Germany	5 410	1 670	3 580	50	90	10 800
United Kingdom	3 640	1 550	2 740	20	140	8 090
France	4 640	790	1 250	180	60	6 920
Italy	3 810	1 030	380	150	10	5 380
EEC	20 680	6 990	9 540	400	340	37 950
Japan	9 050	450	2 420	320	120	12 360
Canada	3 410	1 800	610	770	60	6 650
Australia	1 150	230	1 120	50	0	2 550

(a) Included non fuel products such as naptha, bitumen solvents, etc. and refinery losses. Bunker fuel is excluded.
(b) Black coal and lignite.
(c) Hydro and nuclear power are at the low factor, i.e. the quantity of electricity generated.

Source: OECD, *Energy Balances for OECD Countries, 1974-76*, Paris 1978.

Australia, these differ slightly from those recommended by the Department of National Development[1].

SECTORAL ENERGY CONSUMPTION IN AUSTRALIA

Energy consumption can be estimated at various points in its path of usage, and can be categorised in various ways, such as by primary fuel type, by sector of use, or by energy form at the point of use. It is worthwhile attempting to combine these categories to give a picture of energy flows in the Australian economy from primary source to final use. Each stage of energy use results in the production of useful work or heat, with some portion of the input energy going to waste (also as heat).

Energy flows for Australia have been examined in recent literature by Hawkins[2] and Kalma[3]. Hawkins estimated the sectoral use of energy for three separate years, 1951-62, 1961-62 and 1971-72. He presented a useful discussion of energy measurement at various stges in its flow path, although the scope of his paper was limited by the choice of sectors where for example, energy consumption by private road vehicles was aggregated with the household sector. Kalma analysed the efficiencies attained at each stage of energy conversion and presented a sectoral breakdown of energy use for year 1971-72. A more general discussion of efficiencies in energy utilisation is contained in papers from the Institution of Engineers' Energy Conference[4].

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(1) Department of National Development, *Demand for Primary Fuels in Australia 1976-77 to 1986-87*, Canberra, 1978, Appendix 2.

(2) Hawkins, R.G., *Energy in the Australian Economy*, Australian Economic Review, 4th Quarter, 1976, p.39.

(3) Kalma, J.D., *Sectoral Use of Energy in Australia*, CSIRO, Division of Land Use Research, Technical Memorandum 76/4, Canberra, April 1976.

(4) Institution of Engineers, Australia, *Conferences on Energy - 1977*, Publication 77/6, Canberra, July 1977.

In this section a simplified picture is constructed of energy flows in the Australian economy for the year 1975-76. Some of the relevant statistical data were available only in aggregated form and appropriate assumptions have had to be made on subdivisions for these data.

The demand for primary fuels in Australia has been estimated and published by the Department of National Development(1), and is summarised in Table 2.3.

The consumption sectors in the table are modified aggregations of ASIC(2) categories. The transport and storage sector has been modified to the extent that all oil fuels used as transport fuels have been assigned to this sector from other sectors(3). Thus usage of the following fuels is included in the transport and storage sector:

- motor spirit;
- avgas;
- avtur;
- fuel oil bunkers;
- industrial diesel oil bunkers;
- automotive diesel oil bunkers; and
- duty paid automotive diesel oil.

There is a small but unknown amount of energy associated with ancillary transport used in the storage sector. Ancillary transport covers transport used in warehouses, stockpiles etc.

In the Transport and Storage category, coverage was limited to fuels uplifted in Australia, i.e. it covered direct energy

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(1) Department of National Development, *End Use Analysis of Primary Fuels Demand, Australia, 1973-74 to 1986-87*, Canberra 1978, Table 1.
(2) ABS, *Australian Standard Industrial Classification*, Canberra (1969 Edition).
(3) Information supplied by Department of National Development.

TABLE 2.3 - ESTIMATED CONSUMPTION OF PRIMARY FUELS BY SECTOR, AUSTRALIA, 1975-76

(PJ)

Fuel Type	Sector					TOTAL
	Agriculture/ Mining	Industrial	Transport & Storage	Domestic/ Commercial	Electricity Generation	All Sectors
Solid Fuels	26	418	Neg	24	675	1 144
(per cent)	(2)	(37)	(-)	(2)	(59)	(100)
Petroleum Products	93	324	699	100	42	1 258
(per cent)	(7)	(26)	(56)	(8)	(3)	(100)
Natural Gas	23	106	1	38	45	213
(per cent)	(11)	(50)	(-)	(18)	(21)	(100)
Hydro-electricity	-	-	-	-	56	56
(per cent)					(100)	(100)
TOTAL	142	848	700	163	818	2 671
(per cent)	(5)	(32)	(26)	(6)	(31)	(100)

NOTE: - Indicates not applicable.

Source: Department of National Development, *End-use Analysis of Primary Fuels Demand, Australia, 1973-74 to 1986-87*. Canberra 1978, Table 1.

consumption by domestic transport and by international transport within Australia. Energy categories excluded were fuels uplifted outside Australia by international aircraft and shipping.

From a total input of primary fuels for electricity generation of 818 PJ[(1)], the quantity of electricity generated by 247 PJ. After allowing for auxiliary and transmission losses of 15 per cent, the energy equivalent of electricity finally supplied to consumers amounted to 210 PJ (0.058GWh)[(2)]. Thus the overall efficiency of production and transmission was 26 per cent.

A summary of electricity production data for 1975-76 is set out in the first column of Table 2.4. It was then reallocated three times in order to correspond to the modified ASIC categories of Table 2.3. The first two of these reallocations are set out in Table 2.4, using the assumptions shown in footnotes to the table.

The levels of electricity consumption displayed in the right hand column of Table 2.4 were then regrouped in Table 2.5 to correspond with the four aggregated sectors employed in Table 2.3. Table 2.5 shows the estimated use of electricity and primary fuels by each sector.

An indication of the efficiency of input energy utilisation is set out in Table 2.6. Mean efficiency for the different sectors were based on BTE estimates derived from Wall et al[(3)]. Data from Table 2.6 are used along with data from other tables in this chapter to derive the flow of energy from the input stage to final output as shown in Figure 2.1.

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(1) 1 Petajoule (PJ) = 10^{15} Joule.
(2) The Electricity Supply Industry in Australia 1975-76, Melbourne, April 1977, Table 6.
(3) Wall, T.F. et al, *Energy Use and Conservation in Industry in Conference on Energy 1977*, Institution of Engineers, Australia, Publication No 77/6, Table 1.

TABLE 2.4 - CONSUMPTION OF ELECTRICITY BY SECTOR, AUSTRALIA, 1975-76

	Published[a] Data (GWh)	First[b] Reallocation (GWh)	Second[c] Reallocation (GWh)	Second[c] Reallocation (PJ)
Residential	23 302	23 302	23 302	84.0
Public lighting	467	467	467	1.5
Commercial	33 749 (Commercial, Agriculture, Industrial, Mining)	11 250 (Commercial, Agriculture)	10 125	36.5
Agriculture			1 125	4.0
Industrial		25 000 (Industrial, Mining)	20 700	74.5
Mining			1800	6.5
Transport	700	700	700	2.5
TOTAL	58 218[d]	58 218	58 218	209.5

(a) Electricity Supply Association of Australia, *The Electricity Supply Industry in Australia 1975-76*, Melbourne, April 1977, Table 6.

(b) Supply allocated between Commercial/Agriculture and Industrial/Mining in the ratio 1:2, i.e. it was assumed that the combined ratio for Victoria, Queensland and South Australia applied to Australia as a whole.

(c) Division based on Kalma, J.D. *Sectoral Use of Energy in Australia*, CSIRO, Division of Land Use Research, Technical Memorandum 76/4 Canberra, April 1976, with ratios taken as:
Commercial:Agriculture = 9:1
Industrial:Mining = 92:8.

(d) Excludes an estimated 1 PJ consumed in the Northern Territory.

Source: See notes above.

TABLE 2.5 - ESTIMATED SECTORAL CONSUMPTION OF ELECTRICITY AND PRIMARY FUELS, AUSTRALIA, 1975-76

(PJ)

Fuel Type	Sector				TOTAL
	Agriculture/ Mining	Industrial	Transport & Storage	Domestic[a] Commercial	All Sectors
Electricity	10	75	3	122	210
(per cent)	(5)	(36)	(1)	(58)	(100)
Solid Fuels	26	418	Neg	24	468
(per cent)	(6)	(89)	(-)	(5)	(100)
Petroleum Products	93	324	699	100	1 216
(per cent)	(8)	(27)	(57)	(8)	(100)
Natural Gas	23	106	1	38	168
(per cent)	(14)	(63)	(-)	(23)	(100)
TOTAL	152	923	703	285	1 063
(per cent)	(7)	(45)	(34)	(14)	(100)

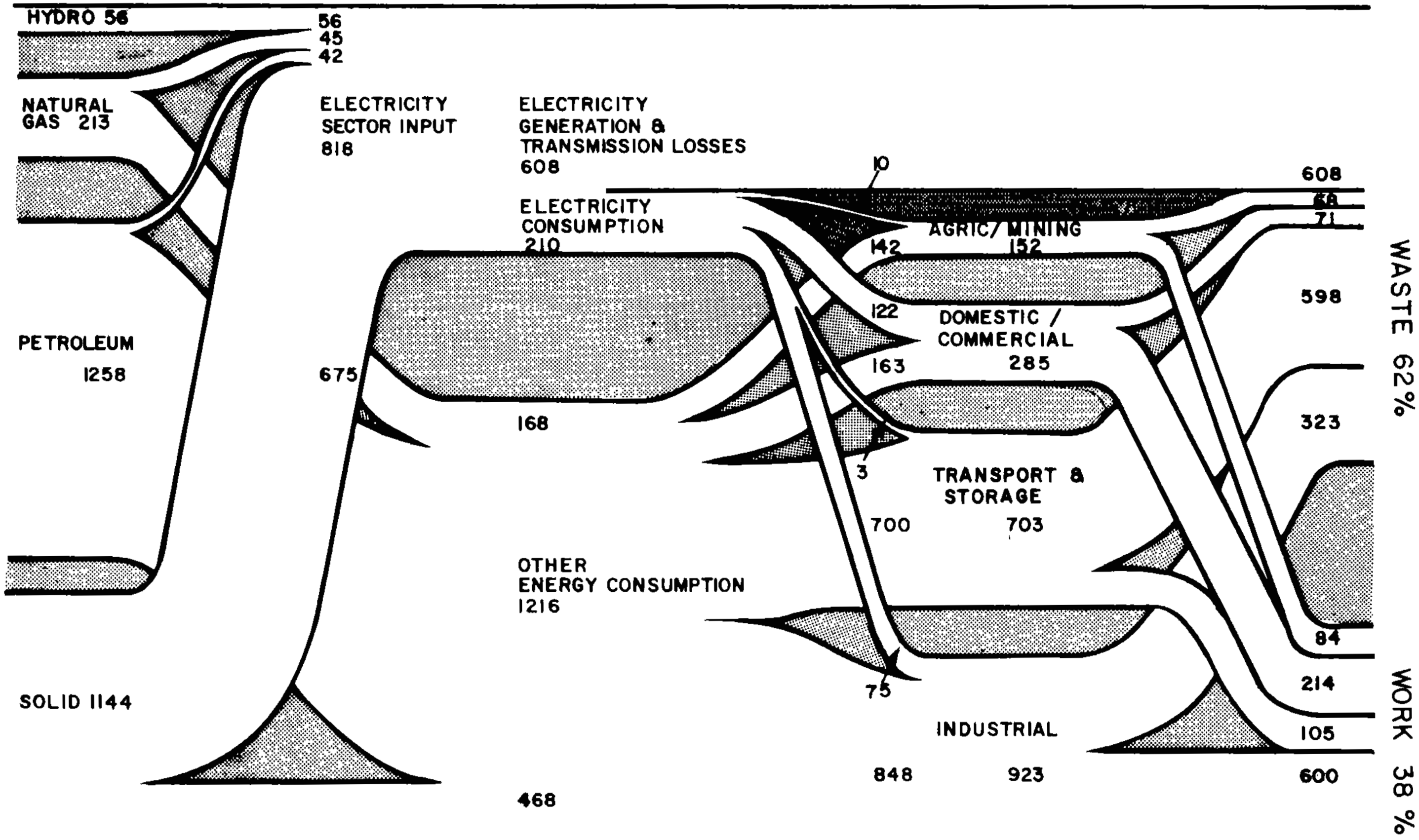
Note: Primary fuels used in electricity production are excluded.
'neg' indicates negligible.

Source: Derived from Table 2.3 and 2.4 (see Text).

TABLE 2.6 - REPRESENTATIVE EFFICIENCIES OF INPUT ENERGY USAGE BY SECTORS

Fuel Type	Sector			
	Agriculture/ Mining	Industrial	Transport & Storage	Domestic/ Commercial
Electricity	0.90	0.90	0.90	0.90
Solid Fuels	0.60	0.60	0.10	0.50
Petroleum Products	0.50	0.65	0.15	0.65
Natural Gas	0.50	0.65	-	0.65
MEAN (for sector)	0.55	0.65	0.15	0.75

Source: BTE Estimates based on Wall, T.F. et al, *Energy Use and Conservation in Industry*, in Conference on Energy 1977, Institution of Engineers, Australia, Publication No. 77/6.



TOTAL INPUT = 2671 PJ

UNITS = PJ

NOT TO SCALE

FIGURE 2·1
ENERGY FLOWS IN THE AUSTRALIAN ECONOMY, 1975 – 76

SOURCE: Tables 2.3, 2.5 and 2.6

The figures for sectoral electricity consumption are net of all production, generation and transmission losses. Losses incurred in the production of secondary fuels other than electricity, such as coke, briquettes and manufactured gas are included in sectoral consumption.

The overall efficiency of energy consumption for Australia as a whole for 1975-76 is estimated from Figure 2.1 at 38 per cent. The efficiency of energy utilisation in the transport and storage sector is seen to have been much lower at an estimated 15 per cent.

Data for Figure 2.1 were derived from tables as follows, reading from the left of the figure:

Column in Figure 2.1	Source
1	Last column, Table 2.3
2	Second last column, Table 2.3
3	Last column, Table 2.5 and the text
4	Body of Table 2.5
5	Last row, Table 2.5
6	Last row, Table 2.6 and column 5, Figure 2.1.

ENERGY CONSUMPTION IN THE TRANSPORT SECTOR

Dependence Upon Petroleum Based Fuels

From Table 2.3, the Transport and Storage sector was estimated to have accounted for 26 per cent of total primary fuel consumption in 1975-76[1]. In 1970-71, domestic transport's

(1) As discussed in the previous section, this does not take into account indirect energy expenditure in the transport sector.

share was also 26 per cent(1), indicating that there had been no significant change relative to other sectors over the period 1970-71 to 1975-76. Of all petroleum fuels used in Australia, domestic transport's share showed a slight increase from 54 per cent in 1971-72(2) to 56 per cent for 1975-76 as indicated in Table 2.3.

During this period, road transport maintained its dependence upon motor spirit and automotive distillate, with no significant usage of any non-petroleum based fuels emerging. Air transport has similarly remained reliant upon the petroleum fuels - aviation gasoline and aviation turbine fuel.

By 1975-76 the railways had completed the transition from coal fired steam to diesel electric locomotives which had commenced after World War II. Coal fired locomotives were no longer operating on scheduled services, although some were retained for special trips. Electric locomotives and trains have been increasingly employed in the New South Wales and Victorian systems, and sections of the urban rail network in Brisbane are at present being electrified. Electric power has continued to comprise a significant proportion of railways' direct energy consumption.

Trams have continued to operate in two cities, Melbourne and Adelaide, with the overall task performed by them remaining fairly steady over the period 1970-71 to 1975-76. Shipping continues to be totally dependent on petroleum fuels.

While it is beyond the scope of this study to analyse future energy options for Australia's transport, it is clear that all

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(1) Clark, N.F. and Associates, *Occasional Paper 2; Transport and Energy in Australia Part 1 - Review*, Bureau of Transport Economics, Canberra, 1975, p.22.

(2) Department of Minerals and Energy, *End-use Aanalysis of Primary Fuels Forecast, 1971-72 to 1984-85*, Canberra, August 1974, Table 1.

the modes will continue to be dependent upon liquid fuels for a considerable time into the future.

Measuring the Energy Efficiency of Transport

Energy Efficiency

Energy efficiency is strictly a dimensionless ratio which for a given process relates the useful energy output to the required energy input. In the case of transport it is customary to relate energy consumption to the transport task which is performed rather than to a technical measure such as newton-metres of work done. This enables the energy efficiency of transport systems performing a range of transport tasks to be measured. Thus, the energy efficiency of particular modes can be monitored by successive measurement over a period of time.

The overall energy expenditure in the transport sector is the total of all direct (propulsive) energy uses and various indirect expenditures related to the transport infrastructure, such as the construction and operation of facilities, and the manufacture and maintenance of vehicles. Dominant among these energy forms is propulsion energy. It is also most readily measured and can be most readily attributed to the performance of a given task.

Energy Intensiveness

The simplest measure of relative energy efficiency is the propulsion energy expended in performing a unit of task, expressed in MJ per passenger-km or per tonne-km. This is denoted the direct energy intensiveness or simply the energy intensiveness. It is related in an inverse sense to energy efficiency; thus a low level of energy intensiveness implies a high relative energy efficiency.

For a particular transport operation the energy intensiveness is determined by the technical characteristics of vehicles, such as propulsion efficiency and vehicle mass, by the mode of operation, and by the level of utilisation (vehicle occupancy or load factor) which is achieved. For a transport mode, the energy intensiveness is a statistical average for all vehicles in the mode.

In the following chapters of this report, estimates are presented of energy intensiveness for passenger and freight operations in each transport mode.

These estimates have been developed as input to time series which will enable changes in the performance of each mode to be monitored. Where methods of estimation are similar, data from Occasional Paper 4 for particular modes would comprise the first values in the time series.

The aggregated nature of the data available for this study did not permit any degree of dissection within modes. Thus the estimates should be interpreted as being only indicative, since the characteristics of a particular operation may differ sharply from the modal average. There are severe limitations on the use of energy intensiveness data for comparisons between modes. These limitations are discussed below.

The level of service provided by a transport system is measured with a range of parameters such as transit time, comfort, frequency, access and cost. In a situation where the same task is performed by different systems, a comparison of their relative energy efficiencies may be of little value if the levels of service offered by each differ widely.

Energy intensiveness is particularly sensitive to variations in the utilisation factor. It is true, for example, that urban bus travel is, on average, less energy intensive than urban car travel, and particularly so in peak hour travel. But the reverse may be true during off-peak periods if buses are lightly loaded. Again this illustrates the danger of obtaining a misleading picture if general modal average values are taken to represent particular cases(1).

In the operation of government freight railways, for example, it is generally the case that long distance trains carrying bulk goods achieve a significantly lower energy intensiveness than for general freight. Thus the overall average energy intensiveness, which is a weighted average over all freight systems, would not be a representative value for either type of opertion taken separately.

A serious practical limitation to the use of energy intensiveness data to compare the 'efficiency' of different modes of transport concerns the problem of circuity of travel by the different modes.

For example, in urban areas, privately owned motor vehicles would generally convey passengers and freight along the most direct route between origin and destination. Public transport vehicles, buses, trams and trains, would be expected to generally have longer, more circuitous routes for any given trip, given the inflexible nature of their route patterns.

The apparent disadvantage of public transport in this regard may be partially offset by the fact that for passenger travel, many passengers walk some distance to board the public transport vehicle, whereas, in the case of travel by car for at least home-based trips, the initial walking phase is not applicable. The extent to which walking can reduce the effective route circuity of public transport is clearly rather complex and involves consideration of walking at both ends of public transport trips and the reduced likelihood of walking at both ends of a private vehicle trip.

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(1) The BTE is currently undertaking a study of energy intensiveness for a series of specific tasks using different modes which will permit direct comparison.

In non-urban areas, travel by air is usually the least circuitous. The relative circuity of travel by land and sea modes would depend on an assessment of all origins and destinations as well as the natural barriers which may act to affect route circuity.

In the above discussion there has been no mention of indirect transport energy consumption and its likely influence upon energy efficiency. Energy consumed in infrastructure activities such as construction and manufacturing may offset or reinforce apparent margins of energy efficiency between systems. It is important to consider whether this factor may in effect undermine the primary intent of transport energy conservation programs since they often take into account only the direct energy savings of alternative transport proposals. The extent to which indirect energy can be assessed in a generalised study of energy usage such as this is limited by a lack of data, although some preliminary estimates are presented later in the report.

In view of the foregoing remarks, great care should be exercised in the use of energy intensiveness data.

Energy consumption per vehicle-kilometre

Another energy measure, which relates to energy usage rather than to energy efficiency, is the energy consumed per vehicle-km. This measure could have application in the formulation of large scale energy conservation measures affecting whole classes of vehicles. It has been calculated for land-based transport modes (where possible), as it is considered that these would be the modes most affected by energy conservation policies.

However, as stated above in the context of energy intensiveness measurements, data on energy consumed per vehicle-km for particular types of vehicle or in particular transport operations may differ sharply from the modal average. Thus the data should be used with caution in making comparisons between modes.

CHAPTER 3 - ROAD TRANSPORT

INTRODUCTION

This chapter describes the transport task and direct energy consumption for all non-military road vehicles including cars, station wagons, motorcycles, commercial vehicles and buses. Its scope is restricted to vehicles performing a passenger or freight task on public roads. it does not cover off-road use of vehicles or their use in sporting activities. Trams are included under rail transport and their contribution to the transport task is described in Chapter 4.

The main sources of statistical data describing the utilisation of road transport are the periodical surveys of motor vehicle usage conducted by the ABS. This chapter draws heavily upon the most recent of these, which covers the twelve-month period which ended on 30 September 1976(1). Its results were released progressively through 1978. Earlier surveys covered corresponding periods in 1963 and 1971.

The 1976 survey output tables gave an extensive analysis for all road vehicles (excepting buses) of distance travelled, and, for freight vehicles, of tonnes carried and tonne-km achieved. They provided a more limited analysis of vehicle occupancy levels and fuel consumption. Several of the tables are included in this paper. A selection is included in the text of this chapter, while the remainder are contained in Appendix V. Explanations of category headings are given in Appendix I.

For buses, data describing the distance travelled, patronage, fuel consumption, and details of bus operations were derived

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(1) ABS, *Survey of Motor Vehicle Usage, 12 months ended 30 September 1976*, Canberra 1978, Ref No. 9202.0

from the latest ABS Survey of Bus Fleet Operations[1], released in 1979.

The scope of this chapter does not include details of the road vehicle fleet, but such information is readily available from the 1976 Motor Vehicle Census, conducted by the ABS, which provided a breakdown of the numbers of each category of road vehicle on register as at 30 September 1976. These categories were dissected by make of vehicle and year of manufacture, and for freight vehicles by tare weight as well.

ROAD TASK

In this section it was assumed that the road task performed by cars and station wagons, motorcycles, and buses was primarily for the carriage of passengers, so that any freight carried would be incidental to the passenger role. Trucks on the other hand are used almost entirely for freight transport and it is reasonable to assume that their contribution to the passenger task was negligible. Utilities and panel vans contribute to both the freight and passenger tasks. To differentiate between the two it was arbitrarily assumed that utilities and panel vans used for business travel primarily perform a freight task, but during private travel and travel to and from work they mainly undertake a passenger task.

The total distance travelled by road vehicles is indicated in Table 3.1. The total distance grew from 81 051 x 10^6 km in 1970-71 to 101 507 x 10^6 km in 1975-76, an increase of 25 per cent. Components of the growth for each vehicle category are shown in Table 3.1.

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(1) ABS, *Survey of Bus Fleet Operations* Year ended 30 June 1976, Canberra, Ref 9203.0.

TABLE 3.1 - SUMMARY OF THE TOTAL AND AVERAGE DISTANCE TRAVELLED BY ROAD VEHICLES, 1976,[a] AND COMPARISON WITH 1971

Vehicle Type	Total Distance ($km \times 10^6$)	Total Distance (per cent)	Mean Distance (km)	Growth in total distance, 1971 to 1976, as percentage of 1971 figures (per cent)
Cars and Station Wagons	78 531	(77)	15 378	+23
Motorcycles	1 641	(2)	5 586	+62
Utilities and Panel Vans	12 290	(12)	16 860	+43
Trucks	8 457	(1)	18 495	+10
Buses	588	(1)	33 901	-10
TOTAL	101 507	(100)	-	+25

(a) Year ended 30 June for buses; year ended 30 September other vehicles.

Source: ABS, *Survey of Motor Vehicle Usage*, Year ended 30 September 1976, Canberra, 1978, Ref 9202.0. Tables 1A, 1B.
ABS, *Survey of Bus Fleet Operations*, Year ended 30 June 1976, Canberra, Ref 9203.0, Tables 3A, 4B.
Clark N. and Associates, *Occasional Paper 4: Transport and Energy in Australia Part 2 - Consumption by Categories*, Bureau of Transport Economics, Canberra, 1975.
ABS, *Survey of Motor Vehicle Usage*, Year Ended 30 September 1971, Canberra 1973, Ref 14.4.
ABS, *Survey of Bus Fleet Operations*, Year Ended 30 June 1971, Canberra 1973, Ref 14.18 Table 1.

In Tables 3.2 and 3.3 the total distance travelled is dissected by area of operation and by travel purpose respectively. From Table 3.2 it can be seen that 62 per cent of all vehicle-km achieved in 1975-76 could have been attributed to urban driving. Table 3.3 shows that 49 per cent of the total distance was undertaken as private travel, with business travel accounting for 29 per cent and the remainder being travel to and from work.

Cars and Station Wagons

Between 1970-71 and 1975-76, the relative proportions of urban and non-urban travel by cars and station wagons remained fairly constant. In 1975-76 these measured 65 and 35 per cent respectively (Table 3.2 refers). From Table 3.3, the proportion of car-km attributable to private travel in 1975-76 was 56 per cent, with work and business travel accounting for 24 and 20 per cent respectively. In Appendix V, Table V.1 gives a further dissection of total car travel by state of registration and area of operation. Similarly Table V.2 gives a division by state of registration and journey purpose. A two way classification of travel by area of operation and journey purpose was not available from the 1976 Survey of Motor Vehicle Usage.

In 1975-76 the occupant task for cars and station wagons totalled 155.67×10^9 occupant-km[(1)] an increase of 24 per cent since 1970-71. Dividing this figure by the total distance travelled gave an average occupancy rate of 1.982 persons per vehicle. The total occupant-km is apportioned by state of Registration in Appendix V, Table V.10.

Of the total occupant-km achieved, 78.51×10^9 occupant-km were achieved in metropolitan (capital city) travel[(2)], at

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(1) See Appendix V, Table V.9.
(2) See Appendix V, Table V.9.

TABLE 3.2 - TOTAL DISTANCE TRAVELLED BY ROAD VEHICLES BY AREA OF OPERATION, 1976 [a]

(km x 10^6)

Vehicle Type	Capital City	Provincial Urban	SUBTOTAL - Urban	Rest of State	Inter-State	SUBTOTAL - Non Urban	TOTAL
Cars and Station Wagons	43 130	7 921	51 051	23 669	3 811	27 480	78 531
Motorcycles	785	187	972	603	67	670	1 641
Utilities and Panel Vans	5 297	1 468	6 765	4 985	540	5 525	12 290
Trucks	3 377	750	4 127	3 623	707	4 330	8 457
Buses	287	120	407	146	35	181	588
TOTAL	52 875	10 447	63 322	33 025	5 160	38 185	101 507
(per cent)	(52)	(10)	(62)	(33)	(5)	(38)	(100)

(a) Year ended 30 June for buses; year ended 30 September for other vehicles.

Source: ABS, *Survey of Motor Vehicle Usage*, Year ended 30 September 1976, Canberra, 1978, Ref 9202.0, Table 2A.
ABS, *Survey of Bus Fleet Operations*, Year ended 30 June 1976, Canberra, Ref 9203.0 Table 5.
Bureau of Transport Economics estimates.

TABLE 3.3 - TOTAL DISTANCE TRAVELLED BY ROAD VEHICLES BY PURPOSE, 1976 (a)

(km x 10^6)

Vehicle Type	Purpose							TOTAL
	Business - Laden	Business - Unladen	SUBTOTAL - Business	Paid to and from work	Unpaid to and from work	SUBTOTAL - to and from work	Private travel	All purposes
Cars and Station Wagons	-	-	15 584	2 435	16 197	18 632	44 315	78 531
Motorcycles	-	-	172	47	611	658	811	1 641
Utilities and Panel Vans	4 449	1 920	6 369	336	1 731	2 067	3 854	12 290
Trucks	5 395	2 309	7 704	59	246	305	448	8 457
Buses	-	-	-	-	294	294	294	588
TOTAL	9 844	4 229	29 829	2 877	19 079	21 956	49 722	101 507
(per cent)	(10)	(4)	(29)	(3)	(19)	(22)	(49)	(100)

(a) Year ended 30 June for buses; year ended 30 September for other vehicles.

Source: ABS, *Survey of Motor Vehicle Usage*, Year ended 30 September 1976, Canberra, 1978, Ref 9202.0, Table 7A.
ABS, *Survey of Bus Fleet Operations*, Year ended 30 June 1976, Canberra, Ref 9203.0 Table 5.
Bureau of Transport Economics estimates.

an apparent average occupancy rate of 1.82 persons per vehicle. This occupancy rate of 1.82 is considerably higher than the generally accepted figure of about 1.4 to 1.5. Table 2.4 of Occasional Paper 4 sets out estimates of occupancy rates for various trip purposes based on a number of transportation studies. Estimated occupancy rate for all areas and for all trip purposes was 2.0. This agrees quite well with the figure of 1.98 derived above from the ABS data. The occupancy rate estimated in Occasional Paper 4 for Capital City and Provincial Urban areas in 1971 for all trip purposes was 1.5, while for the Rest of State and Interstate areas, the rate was estimated as 2.9. More recent transport surveys carried out in Canberra and Adelaide have indicated overall urban occupancy figures of 1.32(1) and 1.38(2) respectively.

Because of the large difference between the urban occupancy figure derived from the ABS Survey and that generally accepted, data for urban and non-urban occupancy and occupant-km relating to cars and station wagons contained in Table V.9 were not considered appropriate for use in this report. It was therefore decided to use the figure of 1.5 for urban occupancy as used in Occasional Paper 4. When applied to the vehicle-km data of Table 3.2 and the total occupant-km of Table V.9, a non-urban occupancy figure of 2.88 was obtained, which is very close to the corresponding figure of 2.9 used in Occasional Paper 4.

By combining the values of occupant-km for capital city and provincial urban, a value of 76.58×10^9 occupant-km was

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(1) National Capital Development Commission, *Canberra Short Term Transport Planning Study, Travel Surveys and Data Assembly*, Vol. 1, prepared by John Paterson Urban Systems and P.G. Pak-Poy and Associates, June 1976, Table 3.36.

(2) S.A. Department of Transport and S.A. Highways Department, *Metropolitan Adelaide Data Base Study, Phase 1 Report, Travel Surveys and Data Collection*, prepared by P.G. Pak-Poy and Associates, February, 1978, Table 3.38.

obtained for all urban areas (Table 3.4). data in Table 3.4 are in units of passenger-km, which are equivalent to occupant-km units for cars and station wagons. The difference between 155.67 x 10^9 and 76.58 x 10^9 occupant-km, 79.09 x 10^9 occupant-km, was attributed to non-urban travel, as shown in Table 3.4.

The 1976 Survey of Motor Vehicle Usage did not provide any subdivision of the passenger task according to journey purpose. Thus details of car occupancy rates for different types of trip, such as business, work or private travel, could not be extracted. In Occasional Paper 4(1) such estimates were based on evidence collected from various transportation studies conducted through the late 1960s and early 1970s. In Occasional Paper 4 the average occupancy rates for business and work trips were assumed to be 1.2 and 1.3 persons per vehicle respectively. A recent BTE study(2) indicated that figures of 1.20 and 1.25 occupants per car for work and business trips respectively were representative of the Melbourne Metropolitan Area in 1975. It was therefore considered reasonable to continue to use occupancy values of 1.2 and 1.3 for work and business trips respectively for Australia as a whole.

These occupancy values can be used to factor the respective distances travelled for business and work purposes (Table 3.3) to derive corresponding estimates of passenger-km. Table 3.5 which uses units of passenger-km, indicates that these were 18.70 x 10^9 passenger-km for business travel and 24.22 x 10^9 passenger-km for work travel. Subtracting these from the total of 155.67 x 10^9 passenger-km left 112.75 x 10^9 passenger-km attributable to private travel. The corresponding occupancy

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(1) Clark N and Associates, Occasional Paper 4, *op.cit.*, Chapter 2.

(2) Lawlor L.C., *Usage Patterns of Urban Cars - Their Effect on Fuel Consumption and Emissions*, Occasional Paper 26, Bureau of Transport Economics, Canberra, 1979, Chapter 5.

TABLE 3.4 - ESTIMATED PASSENGER TASK BY ROAD VEHICLES URBAN AND NON-URBAN, 1976,[a][b] AND COMPARISON WITH 1971

(passenger-km x 10^9)

Vehicle Type	Area of Operation		TOTAL All Areas	Growth Ratio
	Urban[c]	Non-urban[d]		1971 to 1976 of Total Passenger-Km as Percentage of 1971 figure (per cent)
Cars and Station Wagons	76.58 (1.5)	79.09 (2.88)	155.67 (1.98)	+24
Motorcycles	1.03 (1.06)	0.75 (1.12)	1.78 (1.09)	+60
Utilities and Panel Vans	na (1.45)	na (1.70)	9.23 (1.56)	na
Trucks	-	-	-	na
Buses	3.97 (10)	3.62 (20)	7.59 (15)	na
TOTAL	81.58[e] (1.44)[e]	83.46[e] (2.56)[e]	174.27 (1.72)	na

Note: Figures shown in brackets are average vehicle occupancy rates, expressed in persons per vehicle.

'na' denotes information is not available.

(a) Year ended 30 September.
(b) The passenger task is quite distinct from the occupant task. See text.
(c) Includes Capital City and Provincial Urban.
(d) Includes Rest of State and Interstate.
(e) Excluding utilities and panel vans.

Source: Bureau of Transport Economics estimates.
Clark N. and Associates, *Occasional Paper 4: Transport Energy in Australia Part 2 - Consumption by Categories*, Bureau of Transport Economics, Canberra 1975. Table 2.17.

TABLE 3.5 - ESTIMATED PASSENGER TASK BY ROAD VEHICLES BY PURPOSE, 1976(a)(b)

(passenger-km x 10^9)

Vehicle Type	Purpose: Business	Purpose: To and from work	Purpose: Private	TOTAL All Purposes	(per cent)
Cars and Station Wagons	18.70 (1.20)	24.22 (1.30)	112.75 (2.54)	155.67 (1.98)	(90)
Motorcycles	0.19 (1.09)	0.71 (1.09)	0.88 (1.09)	1.78 (1.09)	(1)
Utilities and Panel Vans(c)	-	3.22 (1.56)	6.01 (1.56)	9.23 (1.56)	(5)
Trucks(c)	-	-	-	-	(-)
Buses	na (na)	na (na)	na (na)	7.59 (15)	(4)
TOTAL	18.89(d) (1.20)(d)	28.15(d) (1.32)(d)	119.64(d) (2.44)(d)	174.27 (1.72)	(100)

Note: Figures shown in brackets are average vehicle occupancy rates, expressed in persons per vehicle.

(a) Year ended 30 September.
(b) The passenger task is quite distinct from the occupant task. See text.
(c) Occupant-km attained by utilities and panel vans on business travel, and by trucks for all travel, are assumed to be only incidental to the carriage of freight.
(d) Excluding buses.

Source: Bureau of Transport Economics estimates.

rate for private travel was 2.54 persons per vehicle since the overall occupancy rate was 1.98.

The 1976 survey provided some indication of the respective distances travelled by cars of different sizes, dividing them into three tare weight categories (Table 3.6). If these three groupings are taken as proxy divisions between 'small', 'medium', and 'large' cars respectively, then it can be seen that travel in both Capital City and Other areas was fairly evenly divided amongst the three. Small cars took the largest share (38 per cent) of capital city travel, with large cars taking the greatest share of travel in other areas (also 38 per cent).

TABLE 3.6 - TOTAL DISTANCE TRAVELLED BY CARS AND STATION WAGONS, BY TARE WEIGHT AND AREA OF OPERATION, 1976[(a)]

(km x 10^6)

Tareweight	Area of Operation				TOTAL
(kg)	Capital City	(per cent)	All Other Areas	(per cent)	All Areas
under 1100	16 379	(38)	10 777	(30)	27 156
1100 and under 1300	12 858	(30)	11 361	(32)	24 219
1300 and over	13 886	(32)	13 270	(38)	27 156
TOTAL	43 123	(100)	35 408	(100)	78 531

(a) Year ended 30 September.

Source: ABS, *Survey of Motor Vehicle Usage*, Year ended 30 September 1976, Canberra, 1978, Ref 9202.0 Table 8.

For small, medium and large cars, a further analysis of distance travelled by year of manufacture is given in Tables V.3 and V.4 (Appendix V). These show that in 1975-76, 51 per cent of all car travel was undertaken by cars built between 1970 and 1974; enlarging the period to 1970-76 accounted for 68 per cent of the total.

Motorcycles

In the twelve-month period covered by the Survey of Motor Vehicle Usage, the contribution of motorcycles towards the road passenger task amounted to 1.78×10^9 person-km, with capital city travel accounting for 47 per cent of this figure[(1)]. By dividing the respective person-km for 'Capital City' and 'All Other Areas', (Table V.9) by corresponding distances of travel (Table 3.2), the average occupancy rates were derived. These were 1.06 persons per vehicle for capital city, and 1.12 persons per vehicle for all other areas, with a weighted average of 1.09 persons per vehicle over all areas.

To estimate a division of person-km between urban and non-urban areas, it was considered reasonable to assume that the capital city occupancy rate of 1.06 persons per vehicle also applied to provincial urban[(2)] areas. To retain an overall average of 1.09 persons per vehicle, the occupancy rate for the Rest of State and Interstate[(2)] sectors was calculated to be 1.12 persons per vehicle. These results are displayed in Table 3.4 in units of passenger-km, which are equivalent to occupant-km units for motorcycles.

It is not known how the occupancy rate for motorcycles might have varied according to the purpose of travel, although any such variation is likely to have been small. In the absence

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(1) Appendix V, Table V.9, and Table 3.4.
(2) These terms are explained in Appendix I.

of better information, it was assumed that the overall average rate of 1.09 persons per vehicle was representative for all types of trips. On this basis, the passenger task performed by motorcycles was divided amongst business, work and private travel as indicated in Table 3.5.

Utilities and Panel Vans

For utilities and panel vans, 52 per cent of the total distance travelled was due to business travel, with private travel accounting for 31 per cent, and work travel the remaining 17 per cent(1). In Appendix V, Table V.5, the business component is subdivided according to type of usage.

From the Survey of Motor Vehicle Usage the total occupant-km performed by utilities and panel vans in 1975-76 amounted to 19.19×10^9, at an average occupancy rate of 1.56 persons per vehicle(2). In capital cities the average occupancy rate reduced to 1.45 persons per vehicle. If it is assumed that this rate applied to all urban areas, then the total occupant-km for utilities and panel vans can be divided between urban and non-urban areas following the same procedure as for cars and station wagons.

A non-urban occupancy of 1.70 was required to balance the other occupancy data. Calculation resulted in urban occupant-km of 9.78×10^9 and non-urban occupant-km of 9.41×10^9, which sums to 19.19×10^9 occupant-km.

Not all occupant-km performed by utilities and panel vans could be included as part of the road passenger task, since some portion of the total would be performed incidentally to the

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(1) See Table 3.3.
(2) See Appendix V, Table V.9.

carriage of goods. If it is assumed that utilities and panel vans on business travel are essentially engaged in a freight role, while in private and work travel they are mainly used for passenger transport, then their total distance of travel given in Table 3.3 can be simply apportioned between passenger and freight. Assuming, in the absence of better information, that the overall average occupancy rate of 1.56 persons per vehicle applied to each of the three trip types (business, work and private), then a corresponding division of occupant-km can be made. From Table 3.3 the distance of travel in private and work trips in 1975-76 amounted to 5921 x 10^6 km. Multiplying this by the average occupancy rate of 1.56 persons per vehicle gave the value of 9.23 x 10^9 occupant-km attributable to the passenger task. In Tables 3.4 and 3.5, this figure is shown in units of passenger-km to indicate the difference from the total of 19.19 x 10^9 occupant-km mentioned above. It is not possible to divide the figure of 9.23 x 10^9 passenger-km between urban and non-urban areas. Table 3.5 shows that this figure represented 5 per cent of the total passenger task performed by road vehicles. The remaining occupant-km performed by utilities and panel vans in business travel were not counted towards the passenger task.

It is not possible to compare this data with corresponding data for 1971 since in that year it was assumed that utilities and panel vans performed no passenger task.

Turning to the tonnes carried by utilities and panel vans, Table 3.7 shows that this amounted to 47.95 x 10^6 tonnes in 1975-76, or 6 per cent of the total for all road vehicles. Tables 3.8 and 3.9 give an analysis of distance travelled and tonne-km respectively, according to type of usage. From Table 3.9, the freight task of utilities and panel vans amounted to 4 per cent of the total for all vehicle types. The freight task is analysed by area of operation in Table V.13.

TABLE 3.7 - TOTAL TONNES CARRIED BY UTILITIES, PANEL VANS, TRUCKS AND BUSES, BY STATE OF REGISTRATION, 1976[(a)]

(tonnes x 10^6)

Vehicle Type	State of Registration								
	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUST.
Utilities and Panel Vans	17.51	13.37	4.15	3.51	6.48	1.15	1.44	0.33	47.95
Trucks: (Tareweight tonnes)									
Rigid									
- under 3	23.83	15.53	21.25	4.04	4.57	1.79	0.57	0.44	72.03
- 3 and under 4	21.24	19.84	8.44	6.39	8.26	2.52	0.72	0.47	67.87
- 4 and over	112.33	62.23	58.68	44.54	47.25	14.75	3.59	2.51	345.88
SUB TOTAL									
- Rigid	157.40	97.60	88.37	54.97	60.08	19.05	4.88	3.42	485.78
Articulated									
- under 9	13.44	19.97	6.65	2.42	4.33	4.61	1.05	0.42	52.89
- 9 and under 11	20.32	11.90	8.10	4.31	2.03	3.02	0.51	0.44	50.63
- 11 and over	53.89	11.78	16.85	12.47	15.37	4.57	3.69	0.81	119.41
SUBTOTAL									
- Articulated	87.65	43.66	31.59	19.20	21.72	12.20	5.25	1.67	222.94
SUBTOTAL									
- Trucks	245.06	141.25	119.97	74.17	81.80	31.25	10.13	5.09	708.72
Buses	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	17.98
TOTAL	262.57	154.62	124.12	77.68	88.28	32.41	11.57	5.42	774.64

(a) Year ended 30 June for buses; year ended 30 September for other vehicles.

Source: ABS, *Survey of Motor Vehicle Usage*, Year ended 30 September 1976, Canberra 1978, Ref 9202.0 Table 21.
ABS, *Survey of Bus Fleet Operations*, Year ended 30 June 1976, Canberra, Ref 9203.0 Table 7.

TABLE 3.8 - TOTAL DISTANCE TRAVELLED ON BUSINESS BY UTILITIES, PANEL VANS AND TRUCKS, BY TYPE OF USAGE, 1976[a]

($km \times 10^6$)

Vehicle Type	Type of Usage			TOTAL
	Hire and Reward	Used in own Business	Not Stated	All Usages
Utilities and Panel Vans	646	5 260	118	6 023
Trucks: (Tareweight tonnes) Rigid				
- under 3	363	2 300	13	2 676
- 3 and under 4	274	626	8	909
- 4 and over	979	936	6	1 921
SUBTOTAL - Rigid	1 616	3 862	27	5 506
Articulated				
- under 9	253	115	1	369
- 9 and under 11	417	75	2	493
- 11 and over	961	151	2	1 113
SUBTOTAL - Articulated	1 630	340	4	1 975
Other Truck Type Vehicles	30	191	3	223
SUBTOTAL - Trucks	3 276	4 393	34	7 704
TOTAL	3 922	9 653	153	13 727

(a) Year ended 30 September.

Source: ABS, *Survey of Motor Vehicle usage*, Year ended 30 September 1976, Canberra, 1978, Ref 9202.0 Table 11.

TABLE 3.9 - FREIGHT TASK PERFORMED BY UTILITIES, PANEL VANS AND TRUCKS, BY TYPE OF USAGE, 1976[(a)]

(km x 10^9)

Vehicle Type	Type of Usage			TOTAL
	Hire and Reward	Used in own Business	Not Stated	All Usages
Utilities and Panel Vans	0.176	1.378	0.022	1.577
Trucks: (Tareweight tonnes) Rigid				
- under 3	0.344	1.507	0.008	1.859
- 3 and under 4	0.626	1.334	0.010	1.970
- 4 and over	4.703	3.529	0.024	8.256
SUBTOTAL - Rigid	5.673	6.370	0.041	12.085
Articulated				
- under 9	2.129	0.800	0.006	2.936
- 9 and under 11	4.589	0.629	0.013	5.231
- 11 and over	13.173	1.692	0.009	14.874
SUBTOTAL - Articulated	19.890	3.121	0.029	23.041
SUBTOTAL - Trucks	25.564	9.492	0.070	35.126
TOTAL	25.740	10.870	0.093	36.702
(per cent)	(70)	(30)	neg	(100)

(a) Year ended 30 September.

Source: ABS, *Survey of Motor Vehicle usage*, Year ended 30 September 1976, Canberra, 1978, Ref 9202.0 Table 13A.

Trucks

The occupant task of trucks is shown in Table V.9. Since the entire occupant task of trucks was assumed to be incidental to the carriage of freight, there is no entry in Tables 3.4 and 3.5 for the passenger task of trucks.

The survey of Motor Vehicle Usage listed the distance travelled and tonne-km performed by trucks in a range of cross tabulations. Table 3.7 shows that the total freight tonnage carried by trucks amounted to 708.72 x 10^6 tonnes in 1975-76. Tables 3.8 and 3.9 indicate the distance travelled and tonne-km performed, for each tare weight class of truck, and by type of usage. Further tabulations of distance travelled, tonnes carried and tonne-km performed, are given in Appendix V[(1)].

The total freight task performed by trucks in 1975-76, amounting to 35.126 x 10^9 tonne-km, increased by 35 per cent from the corresponding period in 1970-71. Of this total, 12.122 x 10^9 tonne-km were due to urban freight.

Buses

The ABS Bus Fleet Survey for 1976[(2)] provided data for distance travelled by area of operation, as shown in Table 3.2. Totals were available for Capital City and Provincial Urban travel, but were not directly stated for Rest of State and Interstate travel. Interstate bus travel may derive from the following services - intercapital route, school bus, charter and tour services. It has been assumed that interstate bus travel was accounted for by the sum of intercapital route and tour services. It was also assumed that interstate school bus

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(1) See Tables V.5 to V.8, and V.11 to V.17.
(2) ABS, Survey of Bus Fleet Operations, *op.cit.*, Table 5.

services would be negligible, and that the overestimate involved in assuming that all tour services were interstate would be balanced by the proportion of interstate charter services.

Data were not available on bus distance travelled in terms of journey purpose. In Table 3.3, the possible categories into which bus travel could be subsivided are: unpaid to and from work, and private travel. It has been decided to allocate the total bus travel distance equally between these two purposes. Since bus travel formed such a small proportion of total vehicle-km, the possible error in such estimation is quite small.

Data on passenger-km travelled by buses are not officially collected. An estimate for bus passenger-km travelled in 1971 was included in Occasional Paper 4, but the source document did not explain how the estimate was derived. The Sydney Area Transportation Study contains limited information on bus journey lengths in the Sydney metropolitan area. This shows that the median bus journey length for all journey purposes was 4.6km, with the 90th percentile journey length being 11.2km for the year 1971(1). These measures overestimate the actual bus trip length since walking distances at each end of bus trips were included in total journey distance. From an assessment of the likely bus journey length distribution, it was assumed that the mean length of bus trips for route services in all urban areas was 8km in 1971, and that this could be applied to the year 1975-76 without change. Thus from Table V.23 it was estimated that the 495.74 million passengers carried on route services in metropolitan and other urban areas accounted for 3.97×10^9 passenger-km (see Table 3.4).

An estimate for average urban bus occupancy can be obtained by dividing the urban passenger task (3.97×10^9 passenger-km)

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(1) Sydney Area Transportation Study, Volume 1, Base year (1971), Data Report, Table 6.7.

by the urban travel distance (407 x 10^6 km). This gives an occupancy figure of 10 persons per bus in urban areas. In the absence of official statistics, bus passenger-km in non-urban areas were estimated by assuming that the average non urban bus had a capacity of 40 passengers and operated with a 50 per cent load factor. Applying these quite arbitrary figures to the non-urban bus distance of Table 3.2 (181 x 10^6 km) gives 3.62 x 10^9 passenger-km for the non urban bus passenger task, with an average occupancy of 20 persons per bus.

From the above estimates, overall bus occupancy in all areas is estimated as 15 persons. Data were not available to estimate entries for Table 3.5.

The Freight task of buses during 1975-76, while small in relative terms, was large in terms of tonnes carried, as shown in Table 3.7. As no data were available on the tonne-km achieved by buses, there is no entry for buses in Table 3.9 in terms of tonne-km performed. The freight task of buses has been assumed to be negligible.

DIRECT ENERGY CONSUMPTION

Estimates of fuel consumption by non-military road vehicles were included in the output of the Survey of Motor Vehicle Usage and the Survey of Bus Fleet Operations. In the first-mentioned Survey, a distinction was made between the use of automotive distillate and motor spirit by utilities, panel vans and trucks, but no details of fuel type were collected for cars, station wagons and motorcycles. The consumption by cars of fuels such as automotive distillate or liquefied petroleum gas compared to motor spirit is unknown, but for 1975-76 it was assumed to have been insignificant. The Survey of Bus Fleet Operations contained details of the types of fuel consumed by buses.

In Table 3.10, consumption of motor spirit and automotive distillate is summarised for each category of road vehicle. Assuming that the 'unknown' fuel category consisted of motor spirit and automotive distillate in the same proportions as for known fuel usage, the direct energy consumption was calculated for each vehicle type. This is shown in the right hand column of Table 3.10. The total fuel consumption can be divided by total distance of travel to derive an average rate of fuel consumption, as indicated in Table 3.11. In Appendix V, the total fuel consumption by road vehicles (except buses) is analysed further according to State of Registration and Year of Manufacture(1).

It is of interest to compare the estimated consumption of motor spirit and automotive distillate by road vehicles with the overall consumption of these fuels in Australia during 1975-76(2). Australian consumption of motor spirit in 1975-76 totalled 13 261.0 ML; thus the consumption by motor vehicles of 12 931.2 ML constituted 98 per cent of the total. The remaining portion may be attributed to consumption by off-road vehicles, military vehicles, and non-transport purposes. With respect to automotive distillate, however, motor vehicles accounted for only 29 per cent of non-bunker sales, which totalled 5233.5 ML. Other consumers of this fuel would have included railway locomotives, industrial, mining and agricultural machinery, space heating and small boats, as well as the armed forces.

Referring to Table 3.10, the total direct energy consumption by road vehicles in 1975-76 was 513.0 PJ(3). It displayed a growth of 31 per cent from the 1970-71 total of 392.9 PJ(4).

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(1) See Tables V.18 to V.20.
(2) Taken from Department of National Resources, Petroleum Statistics, *op.cit.*, p.7-9.
(3) 1 Petajoule = 10^{15} Joule.
(4) Clark N. and Associates, Occasional Paper 4, *op.cit.*, Table 3.13.

TABLE 3.10 - TOTAL FUEL CONSUMPTION BY ROAD VEHICLES, 1976[a] AND COMPARISON WITH 1971

Vehicle Type	Type of Fuel: Motor Spirit (ML)	Type of Fuel: Automotive Distillate (ML)	Type of Fuel: Unknown (ML)	TOTAL Energy[c] Content (PJ)	TOTAL Energy[c] Content (per cent)	Growth in energy 1971 to 1976 as Percentage of 1971 figure (per cent)
Cars and Station[b] Wagons	9 873.2	neg	-	342.60	(67)	+26
Motorcycles[b]	96.5	-	-	3.35	(1)	+123
Utilities and Panel Vans	1 698.8	0.5	51.2	60.74	(12)	+90
Trucks	1 291.1	1 373.3	49.0	99.19	(19)	+22
Buses	48.1	143.4	-	7.16	(1)	+1
TOTAL	13 007.7	1 517.2	100.2	513.04	(100)	+31

(a) Year ended 30 June for buses; year ended 30 September for other vehicles.
(b) Details of the type of fuel were not available. All fuel was assumed to be motor spirit.
(c) Energy conversion factors used are: Motor Spirit: 34.7 MJ/L; Automotive Distillate: 38.3 MJ/L. Energy conversion factors from Department of National Development, *End Use Analysis of Primary Fuels, Australia, 1973-74 to 1986-87*, Canberra 1978.

Source: Derived from ABS, *Survey of Motor Vehicle Usage*, Year ended 30 September 1976, Canberra 1978, Ref 9202.0, Tables 33, 36, and unpublished information.
ABS, *Survey of Bus Fleet Operations*, Year ended 30 June 1976, Canberra, Ref 9203.0, Table 10.
Clark N. and Associates, *Occasional Paper 4: Transport and Energy in Australia Part 2 - Consumption by Categories*, Bureau of Transport Economics, Canberra 1975.

It may be noted that in both 1971 and 1976, respondents to the Survey of Motor Vehicle Usage were asked to state the average fuel consumption of their vehicles and annual distance travelled. Estimates of total fuel consumption were then made, based on these estimates of consumption and distance travelled.

Cars and Station Wagons

Table 3.10 shows an estimate of the fuel consumption of cars and station wagons based on the data of Table 3.11. These data assume that the fuel used by cars and station wagons was entirely motor spirit. As stated earlier, it was assumed that only negligible quantities of other fuels were used by these vehicles.

From Table 3.11, the average rate of fuel consumption for the Australian car fleet in 1975-76 was 12.6 L/100 km, a 4 per cent increase over the 1970-71 average of 12.1 L/100 km[(1)]. Information obtained from the Survey of Motor Vehicle Usage allows the fleet average to be subdivided in a two-way table by year of manufacture and tare weight. This is reproduced in Appendix V, Table V.20. This indicates the average consumption rate in 1975-76 of cars manufactured in 1955-59 was 11.1 L/100 km. The figure for cars manufactured in each successive four-year period showed a steady rise up to 12.8 L/100 km for vehicles manufactured in 1970-74. This trend of steadily increasing fuel consumption rate is attributed to the increasing mass and engine capacity of vehicles in the car fleet through the 1960s and early 1970s, coupled with greater use of power-consuming accessories. These factors clearly overshadowed any gains in the operating efficiency of car engines which might have been effected through design improvements over this period.

(1) Clark N. and Associates, Occasional Paper 4, *op.cit.*, p.36.

TABLE 3.11 - AVERAGE RATE OF FUEL, CONSUMPTION BY ROAD VEHICLES (EXCLUDING BUSES), 1976(a)

(L/100km)

Vehicle Type	Type of Fuel		
	Motor Spirit	Automotive Distillate	Unknown
Cars and Station Wagons	-	-	12.6(b)
Motorcycles	-	-	5.9(b)
Utilities and Panel Vans	14.2	15.1	15.4
Trucks	26.1	42.2	39.7

Note: Bus data were not available.

(a) Year ended 30 September.
(b) Assumed to be motor spirit in the absence of any further information.

Source: ABS, *Survey of Motor Vehicle Usage*, Year ended 30 September 1976, Canberra, 1976, Table 33.

This period also saw the introduction of a series of emission control regulations for motor vehicles. The first of these, effective from 1st July 1970, prohibited the release of gases from the crankcase. Australian Design Rule (ADR) 26 came into force on 1 January 1972, limiting the carbon monoxide content of exhaust gases. A further regulation, ADR 27, which followed in 1974, restricted the levels of both carbon monoxide and hydrocarbons emissions. Through design improvements, these early regulations were met by the motor industry largely without influencing the fuel consumption of the vehicle fleet.

A more stringement regulation, ADR 27A, limiting emissions of oxides of nitrogen as well as carbon monoxide and hydrocarbons, was introduced from 1 July 1976. This only overlapped by 3 months the Survey period ending 30 September 1976. This period was insufficient for any influence of ADR 27A on the fleet fuel consumption to be reflected in the Survey tables.

A reversal of the upward trend in fuel consumption rate was evidenced for cars manufactured in 1975 and 1976. These categories attained rates of 12.3 and 12.6 L/100 km respectively in the period to 30 September 1976. Both of these values remained higher however than the fleet average recorded in 1970-71.

The Survey of Motor Vehicle Usage did not provide any distinction between direct energy consumption rates achieved by vehicles under different driving conditions, and in particular, in urban versus non-urban areas. Factors which degrade fuel consumption in urban conditions are low average speeds coupled with the stop-start nature of driving. The average trip distance in urban driving is shorter than for non-urban driving so that the efficiency loss from cold starts has a greater impact upon the average fuel consumption figure achieved in urban areas.

A paper by Glazebrook indicates that in 1975-76, cars and station wagons operating in the Sydney metropolitan area consumed motor spirit at the rate of 14.5 L/100km[1]. The figure of 14.5 L/100km when applied to the distance travelled in all Australian city and urban areas (Table 3.2) implies a fuel consumption rate of 9.1 L/100km in non urban areas to maintain an overall average fuel consumption of 12.6 L/100km. Thus urban consumption would be 60 per cent higher than non urban consumption. This difference appears to be rather large for Australia as a whole.

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(1) Glazebrook G.J., *Fuel Consumption of Motor Vehicles in Sydney*, presented at Seminar and Workshop, 'Can traffic management reduce vehicle fuel consumption and emissions and affect vehicle design requirements', jointly organised by SAE-Australasia Energy Policy Advisory Committee and the Australian Road Research Board on 1 and 2 July 1980. SAE (A) Paper 80013, Table 2.

The difference between fuel consumption rates in different areas is highly sensitive to variations in the actual figures for consumption. Thus if average urban consumption is assumed to be 14.0 L/100km rather than 14.5 L/100km, the non-urban consumption rate becomes 10.0 L/100km, with the ratio of urban to non-urban consumption being 140 per cent. It is quite likely that the mean fuel consumption rate in urban areas other than Sydney was less than 14.5 L/100km since Sydney has particular problems of congestion and gradient.

Information relating to US conditions in 1970 and 1972 is available which suggests that urban fuel consumption was about 40 per cent higher than non urban fuel consumption(1)(2). A difference in fuel consumption rates of 30 per cent was used in Occasional Paper 4(3), based on UK data for 1968. It is felt that it would be more appropriate to utilise the US figure of 40 per cent, particularly since it is closer to the difference implied by the Sydney data of 60 per cent.

The data of Table 3.12 were obtained by firstly applying the mean fuel consumption rates of 14.0 L/100km for the combined city and urban distance travelled of Table 3.2 and the rate of 10.0 L/100km to the non urban distance of Table 3.2. These data were converted to units of direct energy consumption, using the footnotes to Table 3.10.

Motorcycles

The total fuel consumption by motorcycles was estimated in the Survey of Motor Vehicle Usage to be 96.5 ML in 1975-76, equivalent to 3.35 PJ(4). Since there are no diesel powered motor cycles in Australia, all fuel consumed was assumed to be

(1) Hirst E., and Herendeen R., *op.cit.*, p.5.
(2) Pollard J., *op.cit.*, Table 2.1.
(3) Clark N. and Associates, Occasional Paper 4, *op.cit.*, p.36.
(4) See Tables 3.10, 3.11 and 3.12.

motor spirit. While the amount of fuel consumed increased by 123 per cent over the period 1970-71 to 1975-76, the largest proportionate increase for any road vehicle category, motorcycles accounted for less than 1 per cent of the overall direct energy consumed by road vehicles.

In Table V.20 of Appendix V, the average rate of fuel consumption for motorcycles is shown to be 5.9 L/100km. Assuming that urban driving imposes on average a fuel consumption penalty of 40 per cent (as used for cars and station wagons) when compared with non-urban driving, then the fuel consumption rate for urban travel was calculated to be 6.7 L/100km, and for non-urban travel, 4.8 L/100km. Multiplying each by the appropriate distance of travel[(1)] gave the total fuel consumption in urban and non-urban areas. Table 3.12 indicates these, expressed in energy terms.

Utilities and Panel Vans

Table 3.11 shows the average fuel consumption rates for petrol and diesel powered vehicles in this category was 14.2 and 15.1 L/100km respectively. An average rate for all vehicles can be expressed by converting from units of fuel consumption to those of direct energy consumption. The total direct energy consumption, from Table 3.10, divided by the total distance travelled, from Table 3.2, gave an average energy consumption rate of 0.494 GJ/100km.

If it is assumed, as for cars and station wagons, that a direct energy penalty of 40 per cent is incurred by utilities and panel vans in urban driving, then the direct energy consumption can be apportioned between urban and non-urban areas as indicated in Table 3.12. The energy consumption rates used were 0.567 GJ/100km in urban areas and 0.405 GJ/100km in non-urban areas.

(1) See Table 3.2.

TABLE 3.12 - ESTIMATED DIRECT ENERGY CONSUMPTION BY ROAD VEHICLES, URBAN AND NON-URBAN, 1976[a]

(PJ)

Vehicle Type	Area of Operation		TOTAL
	Urban[b]	Non Urban[c]	All Areas
Cars and Station Wagons	247.28	95.32	342.60
Motorcycles	2.24	1.11	3.35
Utilities and Panel Vans	38.37	22.37	60.74
Trucks	48.40	50.79	99.19
Buses	4.96	2.20	7.16
TOTAL	341.25	171.79	513.04
(per cent)	(67)	(33)	(100)

(a) Year ended 30 September.
(b) Includes Capital City and Provincial Urban areas.
(c) Includes Rest of State and Interstate.

Source: Bureau of Transport Economics estimates.

It was stated earlier in the chapter that utilities and panel vans contributed to both the passenger and freight tasks. Table 3.13 shows that in 1975-76, 35.86 PJ was expended by utilities and panel vans on business travel. Using the figure of 60.74 PJ from Table 3.12 for the total energy consumption of utilities and panel vans, it follows that (60.74-35.86) PJ, or 24.88 PJ was consumed in private travel or travel to and from work. It is reasonable to attribute these amounts of direct energy consumption to the freight and passenger tasks respectively.

Thus 59 per cent of direct energy consumption was attributable to the freight role, and 41 per cent to the passenger task.

TABLE 3.13 - DIRECT ENERGY CONSUMPTION OF BUSINESS BY UTILITIES, PANEL VANS AND TRUCKS, BY TYPE OF USAGE, 1976[a]

(PJ)

Vehicle Type	Type of Usage			TOTAL
	Hire and Reward	Used in own Business	Not Stated	All Business Usages
Utilities and Panel Vans	3.70	31.43	0.73	35.86[b]
Trucks	52.57	43.61	0.12	96.30[c]
TOTAL	56.27	75.04	0.85	132.16

(a) Year ended 30 September.
(b) This represents 59 per cent of the total direct energy consumption by utilities and panel vans (see Table 3.12). The remaining 41 per cent, equivalent to 24.88 PJ, is attributed to non-business travel.
(c) Of this amount, 49.30 PJ was consumed in urban areas, and 47.00 PJ was consumed in non urban areas, on business usage.

Source: Derived from ABS, *Survey of Motor Vehicle Usage*, Year ended 30 September 1976, Canberra 1978, Ref 9202.0, Table 36.

Trucks

The direct energy consumption by trucks in 1975-76 totalled 99.19 PJ[1], with consumption of automotive distillate being 17 per cent greater than the consumption of motor spirit in energy terms. The ABS provided separate analyses of fuel consumed by different categories of trucks, alternatively by tare weight or number of axles. These are reproduced in Appendix V[2].

(1) See Table 3.10.
(2) See Tables V.21 and V.22.

In the absence of test data on truck fuel consumption rates in urban and non urban areas, use was made of a paper by Imberger which contains a comparison of the fuel consumption of two identical trucks equipped with petrol and diesel engines(1).

The tests were carried out by computer simulation on the City, Suburban and Highway driving cycle of the US Society of Automotive Engineers (SAE). For petrol operation, consumption on the Highway cycle was 9 per cent higher than on the Suburban cycle. For diesel fuel, the corresponding figure was 15 per cent. Operation on the City cycle also involved higher fuel consumption than on the Suburban cycle. For petrol operation the difference was 22 per cent and for diesel fuel, 13 per cent.

These figures reflect the different responses of petrol and diesel engines to part and full load operation. Since petrol and diesel fuel was used in approximately equal amounts (in energy terms), by trucks in Australia during 1975-76, it is necessary to consider the response of both fuels jointly to low and high speed operation, reflecting urban and non-urban usage. However, it is difficult to compare the City and Suburban cycles with driving cycles appropriate for Australian conditions. It is therefore not clear the extent to which either the City or the Suburban cycle reflects Australian urban driving conditions. It was therefore decided to assume that urban and non-urban energy consumption rates for trucks were equal. The error involved in making this assumption is likely to be small. This contrasts with the assumption used in Occasional Paper 4 that urban consumption was 50 per cent lower than non-urban consumption(2).

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(1) Imberger K., *Trucking in Australia in the 1980s*, The 1979 Convention of the Australian Road Transport Federation, Hong Kong, September 1979, p.15.
(2) Clark N. and Associates, Occasional Paper 4, *op.cit.*, p.36.

From Tables 3.2 and 3.10, the average fuel consumption rate for trucks was calculated as 1.173 GJ/100km. This figure was used as the basis for the estimates of Table 3.12. Table 3.13 gives an alternative analysis of direct energy consumption by type of business usage, derived directly from the Survey of Motor Vehicle Usage.

Buses

The fuel consumed by buses during 1975-76 is listed in Table 3.10 in terms of volumes of petrol and distillate, as well as the energy equivalent of these volumes. From Tables 3.1 and 3.10, a mean energy consumption rate of 1.218 GJ/100km was obtained which was used in these calculations. It may be noted that this figure for mean bus energy consumption was only 4 per cent greater than the corresponding figure for trucks (discussed in the preceding subsection). In Table 3.12, the energy content is allocated to urban and non-urban usages as discussed for trucks above, as it was assumed in the absence of relevant data that buses and trucks would perform comparably in urban and non urban areas as far as energy consumption rates were concerned.

Energy Consumption per Vehicle-km

While not related to the transport task performed by vehicles, the direct energy consumed per vehicle-km permits a comparison of how vehicles use energy. These estimates are based on actual performance during 1975-76 and thus take into account actual occupancy or load factors as appropriate.

Table 3.14 contains the energy usage for all road vehicles. It should be noted that only 49 per cent of the distance travelled by utilities and panel vans has been assessed as relating to freight transport. The corresponding proportion of energy consumed by this category on freight transport was 59 per cent. Table 3.14 shows that passenger cars and derivatives consumed about the same amount of energy per km, and as a class consumed about one-third of the energy of trucks and buses in travelling 1 km.

TABLE 3.14 - ESTIMATED DIRECT ENERGY USAGE PER VEHICLE-KM FOR ALL PURPOSES 1976[a]

(MJ/Vehicle-km)

Vehicle Type	Area of Operation		MEAN	Energy Consumption Ratio (per cent) Urban / Non Urban
	Urban	Non Urban		
Cars & Station Wagons	4.84	3.47	4.36	140
Motorcycles	2.30	1.66	2.04	140
Utilities & Panel Vans	5.67	4.05	4.94	140
Trucks	11.73	11.73	11.73	100
Buses	12.18	12.18	12.18	100

(a) Year ended 30 June for buses; year ended 30 September for other vehicles.

Source: Tables 3.2, 3.12 and text of Chapter 3.

Table 3.15 separates out the non freight segment of transport task and presents energy consumption per vehicle-km for freight transport only. Utilities and panel vans are seen to have consumed about one-half of the energy per km consumed by trucks.

TABLE 3.15 - ESTIMATED DIRECT ENERGY USAGE PER VEHICLE-KM FOR FREIGHT PURPOSES ONLY, 1976[(a)]

(MJ/Vehicle-km)

Vehicle Type	Type of Usage			MEAN
	Hire and Reward	Used in own Business	Not Stated	
Utilities and Panel Vans	5.73	5.98	6.19	5.95
Trucks	16.05	9.93	3.53	12.50[(b)]

(a) Year ended 30 September.
(b) See text for explanation of difference from corresponding Mean in Table 3.14.

Source: Tables 3.8, 3.13.

DIRECT ENERGY INTENSIVENESS

Passenger

The energy intensiveness was calculated by dividing the direct energy consumption by the corresponding passenger or freight task. For passenger vehicles, the energy intensiveness achieved in urban and non-urban areas is shown in Table 3.16. The average energy intensiveness for all passenger vehicles was close to that for cars and station wagons, which was expected since the latter vehicles contributed the major portion of the road passenger task.

The energy intensiveness of cars and station wagons was over 2.5 times higher in urban areas than in non-urban areas. This reflects both the greater rate of fuel consumption and the lower car occupancy levels experienced in urban driving. For buses, the energy intensiveness ratio was just over 2 times. In the case of motorcycles the ratio was closer, being 1.5 times. For utilities and panel vans, values of energy intensiveness for urban and non-urban areas could not be separately identified because, as explained earlier in the chapter, there were no data available to separately apportion the urban and non-urban components of direct energy consumption between passenger and freight roles. Without this dissection being available, respective values of energy intensiveness for these vehicles in urban and non-urban areas could not be calculated.

TABLE 3.16 - ESTIMATED DIRECT ENERGY INTENSIVENESS OF ROAD VEHICLES, PERFORMING A PASSENGER TASK, 1976[(a)]
(MJ/passenger-km)

Vehicle Type	Area of Operation		MEAN
	Urban[(b)]	Non Urban[(c)]	All Areas
Cars and Station Wagons	3.23	1.21	2.20
Motorcycles	2.17	1.48	1.88
Utilities and Panel Vans	n.a.	n.a.	2.70
Buses	1.28	0.57	0.94

(a) Year ended 30 September.

Source: Derived from the following tables (see text):
Cars and Station Wagons) - Tables 3.4 and 3.12
Motorcycles and Buses)
Utilities and Panel Vans - Tables 3.5 and 3.13, (footnote (b)).

As mentioned in the previous section, the total task of utilities and panel vans has been apportioned between the passenger and freight tasks; the passenger task component has been used in these calculations.

Freight

For freight vehicles the energy intensiveness attained in 1975-76 is shown in Table 3.17, derived by dividing the freight task (Table V.13) into the corresponding direct energy consumption (Table 3.13). As explained above, separate details were not available for the energy intensiveness of utilities and panel vans in urban and non-urban areas since the appropriate quantities of direct energy consumption were not known. An alternative analysis of energy intensiveness, by type of usage, is shown in Table 3.18.

TABLE 3.17 - ESTIMATED DIRECT ENERGY INTENSIVENESS OF ROAD VEHICLES, PERFORMING A FREIGHT TASK, (EXCLUDING BUSES) 1976[a]

(MJ/tonne-km)

Vehicle Type	Area of Operation		MEAN
	Urban	Non Urban	All Areas
Utilities and Panel Vans	n.a.	n.a.	22.74
Trucks	4.07	2.04	2.74
MEAN	n.a.	n.a.	3.60

Note: Bus data are not available.

(a) Year ended 30 September.

Source: Derived from Tables V.13 and 3.13.

TABLE 3.18 - ESTIMATED DIRECT ENERGY INTENSIVENESS OF UTILITIES, PANEL VANS AND TRUCKS, BY TYPE OF BUSINESS USAGE, 1976[a]

(MJ/tonne-km)

Vehicle Type	Type of Usage			MEAN
	Hire and Reward	Used in own Business	Not Stated	All Usages
Utilities and Panel Vans	21.02	22.81	33.18	22.74
Trucks	2.06	4.59	1.71	2.74
MEAN	2.19	6.90	9.14	3.60

(a) Year ended 30 September.

Source: Derived from Tables 3.9 and 3.13 (see text).

While utilities and panel vans have been assumed to have a freight carrying role in addition to a passenger role, it has been assumed that trucks had a freight application only. Thus energy used for freight purposes only was taken into account in these calculations. It is not possible to estimate the energy intensiveness of bus freight transport since data on bus tonne-km were not available.

Table 3.17 shows that trucks in urban areas consumed about twice the energy of trucks in non urban areas, per tonne-km.

The energy intensiveness for different categories of truck can also be computed by analysing the appropriate data for direct energy consumption and freight task. Table 3.19 shows a dissection of energy intensiveness according to tare weight of trucks.

TABLE 3.19 - ESTIMATED DIRECT ENERGY INTENSIVENESS OF TRUCKS USED FOR BUSINESS PURPOSES, BY TARE WEIGHT, 1976[a]

Tare Weight (tonnes)	Energy Intensiveness (MJ/tonne-km)
Rigid	
- under 3	11.08
- 3 and under 4	4.97
- 4 and over	3.16
MEAN	
- Rigid	4.68
Articulated	
- under 9	2.15
- 9 to 11	1.68
- 11 and over	1.57
MEAN	
- Articulated	1.67
OVERALL MEAN	2.74

(a) Year ended 30 September.

Source: Derived from Tables 3.9 and V.21 (Appendix V).

CHAPTER 4 - RAIL TRANSPORT

INTRODUCTION

This chapter describes the transport task and direct energy consumption accounted for by light and heavy rail services in Australia. Light rail comprised the metropolitan tram operations in Melbourne and Adelaide. Heavy rail was divided into government and non-government railways. The former comprise the six State systems as well as the National network. The latter (non-government railways) principally serve mining ventures throughout Australia and include a network of sugar cane tramways in Queensland.

Much of the information upon which the chapter is based was derived from the Australian Bureau of Statistics document, 'Rail, Bus and Air Transport'(1). Published annually since 1972-73, this document replaced the previous publication 'Transport and Communication'(2). It contains information upon the railway task and in particular provides detailed analysis of data by system, and in the case of freight operations, by commodity carried.

RAIL TASK

Trams

The transport task performed by trams, outlined in Table 4.1, has remained fairly constant over the period 197-71 to 1975-76, in terms of both vehicle-km travelled and passengers carried. In Melbourne the passenger journeys travelled by tram were about five times greater than for metropolitan buses in 1975-76. In

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(1) ABS, *Rail, Bus and Air Transport, 1975-76*, Canberra 1977, Ref 14.21.
(2) Commonwealth Bureau of Census and Statistics, *Transport and Communication*, Canberra, Ref 14.11.

Adelaide only 26 trams were in use, operating on a single line between the city and the suburb of Glenelg.

TABLE 4.1 - PASSENGER TASK PERFORMED BY TRAMS, 1975-76

City	(Vehicle-km x 10^3)	(Pass. Journeys x 10^3)	(Pass-journeys per vehicle-km)
Melbourne	24 235	106 126	4.4
Adelaide	710	1 248	1.8
TOTAL	24 945	107 375	-

Note: Passenger-km figures were not available.

Source: ABS: *Rail, Bus and Air Tranport, 1975-76*, Canberra 1977, Ref 14.21. Table 25, 26.

Passenger-km data for trams were not directly available from the ABS or annual reports of the operating authorities, but for 1970-71 these were estimated by the Commonwealth Bureau of Roads(1) to total 0.53×10^9. It has not been possible to verify the basis for this estimate. As it was considered that the tram task had probably not changed significantly since then, this figure was taken as an indicative value for 1975-76 and included in this study. The figure implies that the mean trip length was 5 km, which appears realistic for urban travel.

Government Railways - Passenger

Details of urban and non-urban rail services are presented in Table 4.2 for State and National Systems, the latter comprising

(1) Commonwealth Bureau of Roads, *Report on Roads in Australia, 1973*, Melbourne, 1973, Table 4.3.

TABLE 4.2 - PASSENGER TASK OF GOVERNMENT RAILWAYS, 1975-76

System(a)	Area of Operation					
	Urban			Non-Urban		
	(Pass-train-km x 10^6)	(Pass-journeys x 10^6)	(Pass-km x 10^9)	(Pass-(b) train-km x 10^6)	(Pass-journeys x 10^6)	(Pass-km x 10^9)
State:						
NSW	19.90	157.92	3.40*	10.51	1.95	0.87*
Vic	14.72	104.75	1.67	7.82	4.92	0.66
Qld	3.33	32.45	0.42*	4.17	1.83	0.35*
SA	3.64	12.03	0.17	2.03	0.64	0.16
WA	2.25	11.38*	0.10*	1.26	0.35	0.13
Tas(c)	-	0.02	-	0.23	0.13	0.02
SUBTOTAL						
States	43.84	318.55*	5.76*	26.00	9.83	2.18*
National	-	-	-	1.54	0.22	0.22
TOTAL						
Australia	43.84	318.55*	5.76*	27.55	10.05	2.40*

(a) Intersystem traffic is included in the table entry for each system over which it passes. Passenger journeys continuing over both the Trans-Australian and Central Australia systems are counted twice. In 1975-76 these numbered 6 414.

(b) The non-urban passenger train-km entries each include travel on mixed (freight and passenger) trains. Over all systems this was estimated at only 1.6 per cent of total passenger train-km.

(c) Hobart suburban train services ceased operation on 31 December 1974. Thereafter, special excursion trains ran infrequently, with negligible associated train and passenger-km.

NOTE: * Indicates BTE estimates.

Source: ABS, *Rail, Bus and Air Transport, 1975-76*, Canberra 1977, Ref 14.21. Tables 6, 8 and 9, and Bureau of Transport Economics estimates.

the Trans-Australia, Central Australia, North Australia and Australian Capital Territory networks. Passenger-km data for New South Wales, Queensland and Western Australia were not available and BTE estimates were inserted to derive an estimate for the total rail passenger task. These were derived from simple linear regression models, based on the known values of passenger-km, passenger journeys and train-km for the other States (see Appendix II).

During the period 197-71 to 1974-75, the total distance travelled by urban trains remained fairly constant, with a small increase from 39.52 to 43.84 million train-km recorded between 1974-75 and 1975-76. For country services, both train-km and patronage showed a steady decline since 1970-71.

The available data did not allow intersystem and intrasystem passenger travel to be identified separately, or give further analysis of characteristics of passenger travel, such as journey purpose. However, some useful information on this topic can be inferred from ticket sales(1) or travel surveys(2)(3)(4).

Government Railways - Freight

For this analysis it was assumed that no primary freight task was undertaken by the urban rail systems, so that any goods transported by them would be incidental to the carriage of passengers. It was also assumed that all freight was transported in non-urban areas, although some of the freight conveyed would pass through urban areas at some stage. The Government rail freight task is outlined in Table 4.3. The growth in total

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(1) See ABS; Rail, Bus and Air Transport, *op.cit.*, Table 8.
(2) Commonwealth Bureau of Roads, *Report on Roads in Australia, 1973*, Melbourne, 1973, Chapter 4.
(3) Commonwealth Bureau of Roads, *Report on Roads in Australia, 1975*, Melbourne, 1975, Chapter 7.
(4) ABS; *Journey to Work and Journey to School*, Canberra, August 1974, Ref 17.4, Table 12.

tonne-km since 1971-72 was 22 per cent. Systems showing the greatest individual growth were Queensland and Western Australia, due mainly to increased traffic from mining centres. Details of individual commodities transported are not presented here, but a full analysis for each rail system is given by the ABS[(1)].

TABLE 4.3 - FREIGHT TASK BY GOVERNMENT RAILWAYS, 1975-76

System[(a)]	Goods Train-km[(b)] $\times 10^6$	Tonnes Carried $\times 10^6$	Net tonne-km $\times 10^9$
State:			
NSW	24.54	31.23	8.57
Vic	11.27	10.80	3.07
Qld	23.32	33.12	10.10
SA	4.64	6.14	1.69
WA	9.35	17.65	4.54
Tas	1.52	1.61	0.23
SUBTOTAL States:	74.64	100.55	28.20
National	4.05	3.80	2.61
TOTAL Australia:	78.69	204.36	30.81

(a) Intersystem freight is included in the table entry for each system over which it passes. Freight carried over both the Trans-Australian and Central Australia systems is counted twice and in 1975-76 this numbered 173 529 tonnes.
(b) The 'Goods train-km' entries each include travel by mixed (freight and passenger trains). Over all systems this represented only 1.7 per cent of total goods train-km.

Source: ABS, *Rail, Bus and Air Transport, 1975-76*, Canberra 1977, Ref 14.21, Tables 6, 11.

(1) ABS; *Rail, Bus and Air Transport, 1975-76*, Canberra, 1977, Ref 14.21, Table 11.

Non-Government Railways

The non-Government railway systems covered in this analysis are those which operate outside industrial estates, harbour precincts, mines or quarries and which have a total route distance exceeding 2 km. They principally cover railways owned and operated by companies involved in the mining of iron ore, limestone and bauxite. They also include a network of sugar cane railways in Queensland. A summary of their freight task is given in Table 4.4, derived from returns collected by the BTE from the various operating companies.

TABLE 4.4 - FREIGHT TASK BY NON-GOVERNMENT RAILWAYS, 1975-76

Type of Railway	Tonnes Carried $x\ 10^6$	Net Tonne-km $x\ 10^9$
Iron ore railways	83.84	25.75
Sugar tramways	18.84	0.30
Other railways	18.68	0.30
TOTAL	121.36 (a)	26.35

(a) A small portion (4 per cent) of total tonnes carried on non-Government railways was transferred to or from Government systems.

Source: Bureau of Transport Economics, Information Paper, *Traffic Task Performed by Australian Non-Government Railways, 1965-66 to 1975-76*, April 1977.

Tonnage carried by non-Government railways in 1975-76 represented a 54 per cent increase since 1970-71, with a corresponding increase of 91 per cent in tonne-km. There was more than a twofold rise in total tonnage between 19667-67 and 1975-76. This growth in traffic was due mainly to the expansion of mining ventures in the Pilbara region of Western Australia where trains perform a one-way operation delivering iron ore from the mines to the cost. Train weights and axle loads experienced in these operations are among the heaviest in the world. Table 4.5 summarises the contributions of Government and non-Government systems towards the total railway freight task. More than half the total tonnage was due to non-Government systems, although the tonne-km performed by them were not as great, reflecting their shorter average distance of haul.

TABLE 4.5 - SUMMARY OF THE FREIGHT TASK BY RAILWAYS, 1975-76

System				TOTAL All Systems	
Government Railways		Non-Government Railways			
Tonnes Carried x 10^6	Net tonne-km x 10^9	Tonnes Carried x 10^6	Net tonne-km x 10^9	Tonnes Carried x 10^6	Net tonne-km x 10^9
104.36	30.81	121.36	26.35	225.71	57.16

Source: Derived from Tables 4.3 and 4.4.

DIRECT ENERGY CONSUMPTION

Trams

Electric power for Melbourne and Adelaide tram operations is purchased from their repective State electricity grids. For this analysis, the direct energy consumption attributed to trams was measured as the corresponding primary energy content of fuels used by power stations. Thus it took into account losses in electricity generation and supply.

Statistics are published by ESAA[1] of electricity sales and the consumption of primary fuels for each State. Electricity sold for traction purposes in the year 1975-76 for Victoria and South Australia totalled 1.00 PJ and 0.01 PJ respectively[2]. The latter can be attributed entirely to Adelaide tram operations. The former was divided between Melbourne trams (0.20 PJ) and Victorian electric rail (0.80 PJ). The basis for this division is explained in Appendix II.

The efficiency of electricity supply for each State grid was calculated by comparing the total energy content of primary fuels with the total quantity of electricity sold to all customers. These calculations are set out in Appendix II. For 1975-76 the efficiencies for Victoria and South Australia electricity generation were calculated at 21.1 per cent and 24.8 per cent respectively. Thus for Melbourne and Adelaide, the figures for electricity consumption in tram operations were divided by the respective supply efficiency to derive the direct energy consumptions. These are presented in Table 4.6.

<u>Government Railways</u>

The direct energy consumption by Government systems can be calculated from details of diesel oil, petrol, and coal usage,

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(1) Electricity Supply Association of Australia, *The Electricity Supply Industry in Australia, 1975-76*, Melbourne, April 1977, Tables 3 and 7.
(2) 1 Petajoule = 10^{15} Joule.

published by ABS[1]. These are set out in Appendix II. To this must be added the direct energy consumption of electric trains in the New South Wales and Victoria systems[2].

TABLE 4.6 - DIRECT ENERGY CONSUMPTION BY TRAMS, 1975-76

System	Electrical energy consumed for traction (PJ)	Overall efficiency of electricity supply (per cent)	Estimated direct energy consumption (PJ)
Melbourne	0.20	21.1	0.95
Adelaide	0.01	24.8	0.03
TOTAL	0.21	-	0.98

Source: Bureau of Transport Economics estimates.

From the previous section, electricity use attributed to Victorian electric trains was 0.80 PJ in 1975-76. Taking into account losses in electricity generation and supply from Table 4.6, the corresponding direct energy consumption was assumed to be 3.80 PJ. Performing a similar calculation for New South Wales gave a value for the direct energy consumed of 4.87 PJ.

The total usage of diesel oil, petrol and coal by trains in all Government systems amounted to 21.64 PJ. Adding the direct energy consumption of New South Wales and Victorian electric trains, the overall direct energy consumed by Government railways

(1) ABS, Rail, Bus and Air Transport, *op.cit.*, Table 21.
(2) Electrified track in New South Wales comprised all the Sydney urban network, and the rail lines north to Gosford and west to Lithgow. At June 1976 this totalled 446 km. In Victoria, Melbourne urban lines and the Eastern route to Gippsland were electrified, totalling 421 km in 1976.

in 1975-76 totalled 30.30 PJ (listed in Table 4.7). Disaggregation of the total between urban and non-urban areas, and between passenger and freight operations, was not available from published literature and so had to be based on estimates which are summarised below. Detailed calculations and discussion are given in Appendix II.

TABLE 4.7 - DIRECT ENERGY CONSUMPTION BY GOVERNMENT RAILWAYS, BY FUEL TYPE, 1975-76

(PJ)

Fuel Type	Area in which Energy Consumed		TOTAL All Areas
	Urban	Non-urban	
Diesel Oil[(a)]	3.25	18.33	21.58
Coal	-	0.06	0.06
Electricity[(b)]	8.66[(c)]	-	8.66
TOTAL	11.91	18.39	30.30

(a) Includes a small quantity of energy derived from petrol, used by Western Australian Government Railways.
(b) Includes electricity generation and supply losses.
(c) Includes passenger and freight transport.

Source: Tables II.1 and II.7

Urban Operations

The division between urban passenger and freight operations was considered first. For electric trains the total distance travelled was divided as follows: coaching stock (88 per cent), and locomotives (12 per cent). The direct energy consumption of electric trains was assumed to be divided on the same basis. Thus the respective amounts were 7.59 PJ (coaching stock) and 1.07 PJ (locomotives) from Table II.7. The energy consumption rate for electric trains averaged between New South Wales and Victoria was 247 MJ per train-km. Assuming that this rate would hold also for non-electric urban trains, then it can be used to factor their total distance travelled to derive an estimate of direct energy consumption. The results of these calculations are presented in Table 4.7, which shows the total energy consumption by heavy rail in urban area was 11.91 PJ. The energy consumed in non-urban areas was calculated by subtracting this urban component from the total of 30.30 PJ giving a value of 18.39 PJ.

Non-Urban Operations

It was assumed earlier in the Chapter that no primary task was performed by rail systems in urban areas. However, the energy consumed by the transport of freight through urban areas was not negligible and was added to the figure for freight transport in non urban areas to give a total figure for energy for freight transport in non urban areas. The non-urban energy component was divided between passenger and freight operations on the basis of trailing tonne-km performed by each sector.

Table 4.8 shows the direct energy consumption of non-urban rail, equivalent to 19.46 PJ, divided between passenger and freight in the ratio of the trailing tonne-km for each, taken from Table II.10. Over all Government rail services (urban and non-urban), passenger rail accounted for 42 per cent of direct energy consumption. It will be noted that the subtotals in Table 4.8 differ from those in Table 4.7 because 1.07 PJ of electric energy used in urban areas were allocated to non urban freight transport.

TABLE 4.8 - DIRECT ENERGY CONSUMPTION BY GOVERNMENT RAILWAYS, BY TASK, 1975-76

(PJ)

Energy Type/Task	Area of Operation		TOTAL All Areas (per cent)	
	Urban	Non-urban		
Electric				
Passenger	7.59 [a]	-	7.59	(25)
Freight	-	1.07 [b]	1.07	(3)
Diesel [c]				
Passenger	3.25	1.84	5.09	(17)
Freight	-	16.55	16.55	(55)
TOTAL	10.84	19.46	30.30	(100)
(per cent)	(36)	(64)	(100)	

Note: The subtotals for urban and non-urban energy consumption differ from those in Table 4.7. See text.

(a) Includes interurban electric trains.
(b) Energy consumed in urban areas but allocated to non-urban freight transport.
(c) Includes 0.06 PJ energy from coal.

Source: Bureau of Transport Economics estimates.

Non-Government Railways

The direct energy consumption of non-Government railways, set out in Table 4.9, was derived from BTE estimates, based upon information supplied by some of the operating companies. These estimates are detailed in Appendix II. The energy totals for both Government and non-Government railways are summarised in Table 4.10. This shows the direct energy total for non-Government railways amounted to 3.58 PJ in 1975-76. The corresponding figure for 1970-71, estimated in Occasional Paper

4[1] was 7.7 PJ which suggests a decrease in fuel use by private railways over this period. This is somewhat misleading since the 1970-71 figure was estimated, in the absence of better information, by assuming that the energy intensiveness of non-Government railways was similar to that achieved by Government freight systems. In the light of information obtained for this study, it appears that the energy intensiveness of non-Government railways, particularly the iron ore operations, was much lower than was originally estimated. Thus the difference between totals for 1970-71 and 1975-76 must be attributed mainly to estimation differences, and no conclusions can be drawn about the real change in energy use over this period.

TABLE 4.9 - ESTIMATED DIRECT ENERGY CONSUMPTION BY NON-GOVERNMENT RAILWAYS, 1975-76

Type of Railway	Energy Consumption[a] (PJ)
Iron ore railways	3.32
Sugar tramways	0.20
Other railways	0.06
TOTAL	3.58

Note: Bagasse consumption by sugar tramways has been ignored in this analysis.

(1) Clark N. and Associates, Occasional Paper 4, *op. cit.*, Table 3.14.

TABLE 4.10 - SUMMARY OF DIRECT ENERGY CONSUMPTION BY RAILWAYS, 1975-76

(PJ)

Task	System		TOTAL All Systems
	Government	Non-Government	
Passenger	12.68	-	12.68
Freight	17.62	3.58	21.20
TOTAL	30.30	3.58	33.88

Source: Derived from Tables 4.8 and 4.9.

Energy Consumption per Vehicle (or Train) - km

The energy consumed per vehicle-km for trams during 1975-76 was calculated by dividing the data of Table 4.6 (energy consumption) by Table 4.1 (distance travelled). This gave an overall figure of 39.30 MJ per vehicle-km for trams.

Data for distance travelled by Government trains were collected in terms of train-km rather than vehicle-km. By dividing the data of Table 4.8 by Tables 4.2 and 4.3, Table 4.11 was obtained, which contains energy per train-km by area of operation. The Table shows that urban passenger trains consumed more energy per train-km than did freight trains. Data on train-km for non-Government railways were not available.

TABLE 4.11 - ENERGY CONSUMPTION PER TRAIN-KM, GOVERNMENT SYSTEMS, 1975-76

(MJ/Train-km)

Task	Area of Operation		MEAN All Areas
	Urban	Non-urban	
Passenger	247	67	178
Freight	-	224	224
MEAN	247	183	216

Source: Tables 4.2, 4.3 and 4.8.

Trams

If the direct energy consumption from Table 4.6 is divided by the passenger task assumed for trams, then the energy intensiveness derived is 1.85 MJ per passenger-km. The corresponding value for 1970-71 quoted in Occasional Paper 4[1] was 1.3 MJ per passenger-km. It is unlikely that the energy efficiency of trams has decreased during this period but it must be remembered that the direct energy consumption was defined to include also the efficiency of electricity supply. For Victoria, the value of this parameter was calculated in this study as 21.1 per cent for 1975-76, whereas the corresponding value adopted by Occasional Paper 4 for 1970-71 was 26 per cent. This latter estimate is considered to be somewhat high, and probably does not take into account electricity transmission losses. The difference between these values accounts for most of the difference between the above estimates of energy intensiveness.

Passenger Railways

Table 4.12 presents the energy intensiveness of Government passenger rail services. These data were derived by dividing the appropriate totals from Table 4.2 into Table 4.8. The values derived suggest that of the two, a much higher energy intensiveness was associated with urban operations.

There are a number of factors which interact to affect the energy intensiveness of passenger rail transport. Among them are load factors, train mass, average speed, acceleration rate, gradient,

(1) Clark N. and Associates, Occasional Paper 4, *op. cit.*, p.48.

stopping frequency, etc. There appears to be no information readily available to disaggregate the factors which caused the large difference in intensiveness between urban and non-urban areas.

TABLE 4.12 - ESTIMATED DIRECT ENERGY INTENSIVENESS OF PASSENGER RAIL SERVICES, 1975-76

(MJ/passenger-km)

Area of Operation		MEAN
Urban	Non-urban	All Areas
1.88	0.77	1.55

Source: Derived from Tables 4.2 and 4.8.

In Occasional Paper 4, the corresponding energy intensiveness values derived were 1.9 MJ and 1.6 MJ per passenger-km for urban and non-urban rail respectively. It can be seen that the value for urban rail for 1970-71 did not differ significantly from that quoted in Table 4.12 for 1975-76. For non-urban rail, energy intensiveness changed from the 1970-71 value of 1.6 MJ per passenger-km to 0.77 MJ per passenger-km in 1975-76. The large difference is due to the fact that in Occasional Paper 4, direct energy consumption for non urban passenger and freight transport was allocated in proportion to train-km travelled. In this report, however, energy consumption was allocated in proportion to the total trailing mass of each type of train. The latter approach is considered to be much more realistic.

Freight Railways

Estimates of energy intensiveness for Government and non-Government freight railways are summarised together in Table 4.13. The difference between the two reflects the nature of rail operations in each case. Non-Government railways are used almost entirely for transfer of bulk ores and minerals. Their total task is dominanted by the two lines from Mt Newman and Mt Tom Price, upon which heavily loaded ore trains run one-way to the coast. The Mt Tom Price to Dampier line in particular is predominantly downhill on the loaded run. The Government freight operations are a mixture of general freight and bulk goods, with the latter achieving a much lower energy intensiveness. A paper by Thomas(1) cites for Western Australian Government rail operations (1972-73), intensiveness values of 0.50 and 0.17 MJ per tonne-km for general freight and bulk goods operations respectively. These are in general agreement with Table 4.13.

TABLE 4.13 - ESTIMATED DIRECT ENERGY INTENSIVENESS OF FREIGHT RAIL SERVICES, 1975-76

(MJ/tonne-km)

System		MEAN
Government	Non-Government	All Systems
0.57	0.14	0.37

Source: Derived from Tables 4.5 and 4.10.

(1) Thomas M.H., *Energy Utilisation in Transportation and Industry*, paper presented at I.E. Australia Conference, Western Australia's Energy Resources and Utilisation, 1975-2000, Perth, October 1975, Figure 10.

CHAPTER 5 - AIR TRANSPORT

INTRODUCTION

This chapter describes the transport task and direct energy consumption of domestic and international airlines and general aviation in Australia. Task performance and other operational data for Australia's airlines are well documented in a series of annual publications issued by the Commonwealth Department of Transport. A background review of air transport in Australia is presented in the Department of Transport yearbook(1). In this chapter, a distinction is drawn between scheduled services, which form the major portion of airline operations, and non-scheduled flying, such as charter work.

The international task described here is the total of passenger and freight movements between Australia and other nations. The relative levels of inbound and outbound traffic are shown and the contribution of Qantas is compared with that of other international carriers.

AIR TASK

Domestic Airlines - Scheduled Services

In 1975-76. eight airlines were operating scheduled services in Australia and the task performed by them is summarised in Table 5.1. A more detailed analysis of operations for each airline can be obtained from the source document quoted for the table.

The total of 7645 million passengers-km compares with 4973 million performed in 1970-71, an increase of some 54 per cent.

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(1) Australian Department of Transport, *Australian Transport*, Canberra, published annually.

TABLE 5.1 - TASK PERFORMED BY SCHEDULED DOMESTIC AIRLINES, 1975-76

Units of Task	Airline			TOTAL
	Ansett Airlines of Australia	Trans-Australia Airlines	All Others	All Airlines
Distance Flown (km x 10^6)	54.25	53.89	27.78	135.92
Passengers x 10^3	3 949	4 056	1 411	9 416
Passenger-km x 10^9	3.424	3.430	0.791	7.645
Passenger tonne-km x 10^9	0.308	0.309	0.071	0.688
Freight & Mail tonnes x 10^3	58.82	46.29	11.81	116.92
Freight & Mail tonne-km x 10^9	0.057	0.043	0.010	0.110
TOTAL tonne-km by 10^9	0.365	0.352	0.081	0.798

Note: Most freight and mail was carried on services which also carried revenue passengers. Only 27 per cent of freight and mail tonnes, and 22 per cent of freight and mail tonne-km, were carried on non-passenger flights.
Passenger tonne-km are derived from passenger-km using an assumed load factor of 91.5 kg/passenger.

Source: Department of Transport, *Domestic Air Transport Statistics*, Year ended 30 June 1976, Canberra 1977.

An increase of 26 per cent in the freight task occurred over the same period. In terms of tonne-km achieved, the freight task remained small in comparison with that for passengers.

International Airlines - Scheduled Services

The numbers of passengers embarking and disembarking at international airports in Australia are published annually by the Department of Transport(1). Table 5.2 indicates these for 1975-76. Since statistics of the task performed were not available, the passenger-km and freight and mail tonne-km were estimated in this study by multiplying each passenger total by a representative route distance and summing over all routes. For the table, separate estimates were prepared for inbound and outbound traffic for Qantas and all other carriers respecticely. The representative route distances are listed in Appendix III.

The total number of passengers embarking and disembarking amounted to 2.80 million compared with 1.20 million in 1970-71. The corresponding passenger task in 1975-76 was one and a half times greater than that estimated for 1970-71 in Occasional Paper 4(2); with the freight task rising from 0.4×10^9 to 0.75×10^9 tonne-km in this period. As for domestic services, freight movements only contributed a small portion of total tonne-km achieved by air services.

Domestic and International Airlines, Non-Scheduled Services

Non-scheduled flying by international airlines operating to Australia is essentially charter work. for the domestic airlines and Qantas, non-scheduled and non-revenue flying together include charter, flying training, test and ferry, and other work. The

(1) Department of Transport, *Australian International Air Transport Statistics*, Year ended 30 Junbe 1976, Canberra 1977, p.2.
(2) Clark N. and Associates, Occasional Paper 4, *op.cit.*, p.29.

TABLE 5.2 - TASK PERFORMED BY SCHEDULED INTERNATIONAL AIR SERVICES, 1975-76

Units of Task	Into Australia			Out of Australia			TOTAL
	Qantas	All Other	SUB TOTAL	Qantas	All Other	SUB TOTAL	All Services
Passengers x 10^3	640	773	1 413	605	783	1 388	2 801
Passengers-km x 10^9	6.39	7.27	13.66	5.42	7.79	13.20	26.86
Passenger tonne-km x 10^9	0.585	0.665	1.250	0.496	0.712	1.208	2.458
Freight & Mail tonnes x 10^3	16.7	32.5	49.2	13.8	15.9	29.7	78.4
Freight & Mail tonne-km by 10^9	0.167	0.305	0.472	0.123	0.158	0.281	0.753
TOTAL tonne-km x 10^9	0.752	0.970	1.722	0.619	0.870	1.489	3.211

Note: Passenger tonne-km were derived from passenger-km using an assumed load factor of 91.5 kg/passenger.

Source: Department of Transport, *Australian International Air Transport Statistics*, Year ended 30 June 1976, Canberra 1977. Bureau of Transport Economics estimates.

overall amount of non-scheduled flying was small relative to the scheduled task, and an indication of the relative levels can be obtained from the respective hours flown, summarised in Appendix III, Table III.2.

For the domestic airlines and Qantas, the task performed in non-scheduled operations has been estimated by the Department of Transport[1]. That estimated for Qantas contains an unknown proportion performed wholly overseas. The contribution to non-scheduled flying by international airlines other than Qantas was not known but was thought to be small. To obtain an overall estimate it was considered non-scheduled task attributed to all international airlines, i.e. it was assumed that charter flights by other airlines to Australia were equivalent to the portion of Qantas' non-scheduled flights performed wholly overseas. These estimates are incorporated into Table 5.3.

TABLE 5.3 - ESTIMATED TASK PERFORMED BY NON-SCHEDULED AIRLINE SERVICES, 1975-76

Units of Task	Service		TOTAL
	Domestic	International	All Services
Passenger-km x 10^9	0.016	0.150	0.166
Passenger tonne-km x 10^9	0.001	0.014	0.015
Freight tonne-km x 10^9	0.001	0.001	0.002

Source: Department of Transport estimates.

(1) Advice from Research and Planning Branch, Air Transport Policy Division, Department of Transport.

The scheduled and non-scheduled tasks of domestic airlines are shown together in Table 5.5. For international airlines, a summary of the scheduled and non-scheduled tasks is given in Table 5.6.

General Aviation

All civil flying other than the airline services is accounted for under the heading of general aviation. General aviation statistics are grouped into the following types of operation; commuter services, charter, private and business, flying training, aerial agriculture, aerial work, and test and ferry.

Commuter services are regular public air services, carrying revenue traffic under ANR 203 exemption. In 1976, 36 such services were in operation. Operational statistics of commuter services were published by the Department of Transport[1] and the task performed by them is summarised in Table 5.4.

For the other forms of general aviation, the only statistics published were for hours flown, summarised in Appendix III. A direct transport task (principally passenger) would be performed during most charter and private and business flying. This task has been estimated by the Department of Transport (Appendix III) and is presented in Table 5.4.

In the remaining categories, a secondary transport task may be achieved whilst other duties are being performed, although this would be difficult to estimate and for simplicity has been ignored in this analysis.

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(1) Department of Transport, *Statistics of Australian Commuter Air Services*, Year ended 30 June 1976, Canberra 1977.

TABLE 5.4 - ESTIMATED TASK PERFORMED BY GENERAL AVIATION, 1975-76

Units of Task	Service			TOTAL
	Commuter Services	Charter	Private & Business	All Services
Passengers x 10^3	333	n.a.	n.a.	n.a.
Passenger-km x 10^9	0.088	0.128	0.187	0.403
Passenger tonne-km x 10^9	0.008	0.012	0.017	0.036
Freight & Mail tonnes x 10^3	2.172	neg	neg	2.172
Freight & Mail tonne-km x 10^9	0.001	0.008	neg	0.009
TOTAL tonne-km x 10^9	0.009	0.020	0.017	0.045

Source: Department of Transport, *Statistics of Australian Commuter Air Services*, and Department of Transport estimates. Year ended 30 June 1976, Canberra 1977.

TABLE 5.5 - SUMMARY OF THE DOMESTIC AIR TRANSPORT TASK, 1975-76

Units of Task	Service				TOTAL All Services
	Domestic Airlines		General Aviation		
	Scheduled	Non Scheduled	Commuter	Other[(a)]	
Passengers x 10^3	9 416	n.a.	333	n.a.	n.a.
Passenger-km x 10^9	7.645	0.016	0.088	0.315	8.064
Passenger tonne km x 10^9	0.688	0.001	0.008	0.028	0.726
Freight & Mail tonnes x 10^3	116.92	n.a.	2.17	neg	n.a.
Freight & Mail tonne-km x 10^9	0.110	0.001	0.001	0.008	0.120
TOTAL tonne-km x 10^9	0.798	0.002	0.009	0.036	0.845

(a) Comprises charter and private and business flying.

Source: Derived from Tables 5.1, 5.4 and 5.5.

TABLE 5.6 - SUMMARY OF THE TASK PERFORMED BY INTERNATIONAL AIR SERVICES TO AUSTRALIA, 1975-76

Units of Task	Service		TOTAL
	Scheduled	Non Scheduled	All Services
Passengers x 10^3	2801	n.a.	n.a.
Passenger-km x 10^9	26.86	0.150	27.01
Passenger tonne-km x 10^9	2.458	0.014	2.472
Freight & Mail tonne-km x 10^9	0.753	0.001	0.754

Source: Derived from Tables 5.2 and 5.3.

The contribution of general aviation to the total domestic air task is shown in Table 5.5.

DIRECT ENERGY CONSUMPTION

The service statistics for air transport published by the Department of Transport do not include details of aircraft fuel consumption. Only the total consumption of aircraft fuels for Australia can be obtained directly, from records published by the Department of National Development. It is assumed in this analysis that all aircraft fuels[1] procured in Australia are utilised for aircraft use. This is not strictly true since applications such as stationary aero turbines used as generators in small power stations accounted for a small amount, which has been assumed to be negligible.

Customs duty is payable on fuels imported to Australia in a refined state for local use, and excise is payable on locally refined fuels for domestic purposes. Following the method used in Occasional Paper 4, the division of aircraft fuel use between domestic and international operations was estimated by assuming that all aircraft fuels which are exempt from customs or excise are used in international operations, the remainder being attributed to domestic flying. On this basis virtually all aviation gasoline and about 54 per cent of aviation turbine fuel can be attributed to domestic operations, and the remainder to international use.

The fuel consumption statistics published by the Department of National Development include the military use of fuels, which falls outside the scope of this study. After adjusting these accordingly[2], the total usage of fuels in the civilian sector is presented in Table 5.7. Thus, of the total direct energy

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(1) Aviation gasoline and aviation turbine fuel.
(2) Based on information supplied by the Department of Defence, Canberra.

consumption of 64.60 PJ the proportion assigned to domestic use was 40.16 PJ or 62 per cent[1]. The remainder, amounting to 24.44 PJ was uplifted in Australia by international aircraft.

TABLE 5.7 - AIRCRAFT FUELS UPLIFTED IN AUSTRALIA FOR CIVILIAN PURPOSES, 1975-76

(ML)

Fuel Type	Subject to Customs or Excise Duty	Exempt from Duty	Total
Aviation Turbine Fuel	994.57 (36.64)[a]	663.39 (24.44)	1 657.96 (61.08)
Aviation Gasoline	105.06 (3.52)	neg (-)	105.06 (3.52)
TOTAL (PJ)	(40.16)	(24.44)	(64.60)

Note: Energy conversion factors used were:
Aviation Turbine Fuel = 36.8 MJ/L
Aviation Gasoline = 33.5 MJ/L

(a) Figures in brackets are units of PJ.

Source: Department of National Resources, *Petroleum Statistics, Fiscal Year 1976-77*, Melbourne 1977, and information supplied by the Department of Defence, Canberra. Energy conversion rates were obtained from: Department of National Development, *End Use Analysis of Primary Fuels Demand, Australia*, 1973-74 to 1986-87, Canberra 1978.

Domestic Services

An allocation of fuel usage between domestic airline operations and general aviation was estimated by attributing the heat value of all domestic aviation turbine fuel to airline use, and that of aviation gasoline to general aviation. This method of

(1) 1 Petajoule = 10^{15} Joule.

apportionment implicitly assumes that the heat value of any aviation gasoline used by the domestic airlines would balance that of any aviation turbine fuel used by general aviation. This is considered reasonable given that the airlines predominantly use jet or turbo-propellor driven aircraft. This led to 36.64 PJ being attributed to domestic airlines, with 3.52 PJ being assigned to general aviation. This method of estimation may require review in the future due to the growth in the use of jet aircraft in general aviation.

Because of the relatively small component of the airline task due to non-scheduled flying, no attempt was made in this analysis to apportion direct energy consumption between scheduled and non-scheduled airline operations. A division between passenger and freight tasks was made on the basis of relative tonne-km attributable to each, derived from Table 5.5. This division is somewhat arbitrary, since, as pointed out in the footnote to Table 5.1, about 73 per cent of the total freight and mail tonnage was transferred on flights which also carried revenue passengers. These calculations are summarised in Table 5.8 below.

For general aviation, the total direct energy consumption was apportioned between passenger and freight in the same manner as that described above, yielding estimates shown in Table 5.8. Since the total for general aviation was small, and is itself only an estimate, it was not considered worthwhile to apportion it further amongst the various categories of general aviation operations (commuter, charter etc).

International Services

The Department of Transport estimated that, in 1975-76, Qantas consumed 980 ML of aviation turbine fuel, of which about 400

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(1) Department of Transport, unpublished information.

TABLE 5.8 - SUMMARY OF DIRECT ENERGY CONSUMPTION BY AIR TRANSPORT, 1975-76[a]

(PJ)

Task	Domestic			International			SUBTOTAL	TOTAL
	Airlines	General Aviation	SUBTOTAL Domestic	Uplifted in Australia	Uplifted[b] outside Australia	SUBTOTAL[b] International	Uplifted in Australia	All Services
Passenger	31.60	2.83	34.43	n.a.	n.a.	62.99	34.43	97.42
Freight	5.04	0.70	5.74	n.a.	n.a.	19.21	5.74	24.95
TOTAL	36.64	3.52	40.16	24.44[c]	57.76	82.20	64.60	122.36

(a) Excludes military aircraft.
(b) Estimate only.
(c) Energy uplifted by Qantas = 14.76 PJ (400 ML)
Energy uplifted by other carriers = 9.68 PJ (263 ML)

Source: Bureau of Transport Economics estimates.

ML was uplifted in Australia[1]. Consumption by other international carriers on their Australian routes was estimated to have been about 1250 ML. The proportion of this uplifted in Australia was not known directly, but was estimated to have been about two thirds of the amount uplifted by Qantas in Australia.

These estimates indicate that the total fuel used by all international airlines on their Australian routes in 1975-76 amounted to 2230 ML of aviation turbine fuel (equivalent to 82.2 PJ). The amount of this actually uplifted in Australia was assumed to correspond to the quantity of duty-exempt aviation turbine fuel consumed in Australia, which from Table 5.7 amounted to 663 ML or 24.44 PJ. Thus 30 per cent of the estimated direct energy consumption on Australian international routes was uplifted in Australia.

The division between passenger and freight tasks was made in the same manner as for domestic operations, using the tonne-km data listed in Table 5.6. Again no differentiation was made between scheduled and non scheduled flights.

DIRECT ENERGY INTENSIVENESS

By dividing the respective transport task values into the direct energy consumption estimates, the direct energy intensiveness was derived for domestic and international airlines and general aviation. For international airlines, the energy intensiveness was calculated for the combined inbound and outbound tasks. The energy total used in the numerator was derived from estimates of fuel uplifted in Australia plus that uplifted outside Australia by operators on Australian routes. The inclusion of fuel uplifted outside Australia in this calculation is a departure from the assumption used throughout the rest of the report. It was made, however, to permit an estimate to be made of the energy intensiveness of international air transport, and a better comparison with domestic air travel. It is emphasised that the accuracy of the estimate of fuel consumed by international air transport is unknown. This is also true for the estimate of direct energy intensiveness for international airlines, and it should be used with considerable caution.

The values listed in Table 5.9 permit some comparison to be made between the respective energy efficiencies of the domestic and international airlines. The figures suggest that a significantly greater energy efficiency (i.e. lower energy intensiveness) was achieved by the international airlines. Considering Qantas as a representative international carrier to Australia, its passenger and weight load factors achieved in 1975-75 were 61.2 per cent and 57.0 per cent respectively(1). The corresponding factors for domestic airlines averaged 65.4 per cent and 61.5 per cent(2).

TABLE 5.9 - ESTIMATED DIRECT ENERGY INTENSIVENESS OF AIR TRANSPORT, 1975-76

Units of Task	Domestic Airlines	General Aviation	MEAN Domestic Services	International Airlines
Passenger:				
MJ/passenger-km	4.1	7.0	4.3	2.3
Freight:				
MJ/tonne-km	45.4	77.8	47.8	25.5

Source: Derived from the following tables:
Domestic Airlines: Tables 5.5 and 5.8
General Aviation: Tables 5.4 and 5.8
International Airlines: Tables 5.6 and 5.8.

(1) Department of Transport, *Australian International Air Transport Statistics*, *op.cit.*, p.4.
(2) Department of Transport, *Domestic Air Transport Statistics*, Year ended 30 June 1976, Melbourne, p.3.

These sets of values show a decreasing progression of energy intensiveness for general aviation, domestic airlines and international airlines. One contributing cause is that the longer legs of international flights would, on average, allow a greater proportion of cruise flying relative to ascent, descent and turnaround, than for domestic operators. Another factor is that international routes are operated by larger, more fuel efficient aircraft than are used on domestic routes.

The quoted estimates of energy intensiveness for general aviation are slightly high, because the numerator (direct energy consumption) covers all types of general aviation, whereas the denominator (task) is for commuter charter and private and business only. This is difficult to adjust since there was no information available to separately estimate and then remove the direct energy consumption due to other 'non-transport' types of flying such as aerial agriculture.

CHAPTER 6 - SEA TRANSPORT

INTRODUCTION

The movements of commodities by Australian coastal shipping is well documented in bulletins issued periodically by the BTE[1][2] and the Department of Transport[3]. Flows of imports and exports are recorded by the ABS[4][5]. Shipping plays a less important role in passenger transport, although statistics of coastal and international passenger movements by ship are also readily available[6][7]. Thus the shipping task may be readily defined. A useful background description of Australian shipping operations and participation in international trade is given in the Department of Transport yearbook[8].

There are no statistics known to be available which describe the movements of private craft or non-trading vessels such as fishing boats, tugs and official vessels. Many of these would be engaged in activities outside the transport definition, although private pleasure craft in particular could be considered to perform a transport task in the same way that a car or light plane might be used for recreational purposes. However in the absence of published information on small vessels, the scope of this chapter is restricted to activities of passenger and freight trading ships only.

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(1) Bureau of Transport Economics, *Port Authority Cargo Movements*, 1971-72 through 1975-76.
(2) Bureau of Transport Economics, *Australian Sea Freight Movements 1975-76*, AGPS, Canberra, 1977.
(3) Department of Transport, *Port Authority Cargo Movements 1976-77*, AGPS, Canberra 1978.
(4) ABS, *Overseas and Coastal Shipping*, Canberra, Ref 9207.0.
(5) ABS, *Outward Overseas Cargo*, Canberra, Ref 9206.0.
(6) ABS, *Passenger Movements by Sea at Australian Ports*, Canberra, Ref 3405.0.
(7) ABS, *Overseas Arrivals and Departures*, Canberra, Ref 3404.0.
(8) Department of Transport, Yearbook, *Australian Transport*, Canberra, published annually.

Brief mention should be made of the role of passenger ferries, because they form a part of the transport network in some cities notably Sydney and Hobart. Since there is no single chapter covering urban transport, they are most conveniently discussed here although they are not strictly part of the sea transport mode. Their contributions to the overall passenger task and to the total direct energy consumption were both too small to warrant their inclusion in the total energy analysis, but for interest, the level of ferry patronage in 1975-76 is described in Appendix IV.

In this chapter, commodity flows are described using the term 'cargo-tonnes', which is the algebraic addition of cargoes measured by weight (tonnes) and those measured by volume (cubic metres). This follows the convention adopted in some of the source documents. Cargo-tonnes are a convenient way of expressing weight cargoes and volume cargoes in a single measure. In general, most cargoes are recorded by weight, particularly bulk cargoes; thus cargo-tonnes are a good proxy for actual tonnes. In specific cases, such as for cargoes of furniture or other light manufactured items, cargo-tonnes may not be as appropriate as volume tonnes, but since this analysis is essentially an aggregated one taking all cargoes into account, the problem is not considered significant.

While the freight task is well documented in the literature, the same is not the case for the direct energy consumption of shipping. Although total bunker sales in Australia are known(1), their dissection between different types of shipping can only be based on estimates.

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(1) Department of National Resources, *Petroleum Statistics*, Fiscal 1976-77, Melbourne 1977, p.18.

SHIPPING TASK

Coastal Freight

Estimates of Australia's coastal freight task were issued by the BTE[1] and are now published by the Department of Transport. They were derived from the various Bureau information bulletins entitled *Port Authority Cargo Movements* which were in turn compiled from the records of the port authorities.

The coastal freight task performed in 1975-76 is shown in Table 6.1. The tonne-km figures were obtained by multiplying the cargo-tonnes movements by the appropriate port to port distances. The table clearly shows the dominance of bulk commodities, mostly petro-chemical products, minerals and ores, in both intrastate and interstate traffic.

Coastal Passenger

Records of passenger embarkations and disembarkations at Australian ports are presented by ABS[2], dissected in three categories: overseas, cruise and interstate passengers. Since overseas passengers were not relevant in this context, the coastal passenger task has been estimated using the remaining two categories.

No details of itinerary are available for cruise passengers but the number and duration of cruises and passenger totals are recorded. Cruise distances were estimated by multiplying their duration by a representative daily distance covered. The passenger-km were then derived from a further multiplication by the passenger totals. This procedure is set out in Appendix IV.

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(1) Bureau of Transport Economics, Information Paper, *Domestic Sea Freight Traffic Task by Commodity, 1973-74 to 1975-76*, June 1977.

(2) ABS, *Passenger Movements by Sea at Australian Ports*, 1975, Canberra, Ref 3405.0, Table 1.

TABLE 6.1 - FREIGHT TASK PERFORMED BY COASTAL SHIPPING, 1975-76

Freight Type	Interstate		Intrastate		TOTAL	
	Cargo-tonnes x 10^6	Tonne-km x 10^9	Cargo-tonnes x 10^6	Tonne-km x 10^9	Cargo-tonnes x 10^6	Tonne-km x 10^9
Petroleum products	12.81	19.34	5.13	3.47	17.94	22.81
Chemicals, minerals & ores	12.84	51.16	7.46	12.45	20.29	63.61
Metals & mineral products	3.33	7.27	0.13	0.09	3.46	7.36
Manufactured goods	1.28	1.33	0.18	0.04	1.46	1.37
Agricultural products	1.60	2.76	0.12	0.05	1.72	2.82
Other cargoes	2.27	3.10	0.40	0.41	2.67	3.51
TOTAL	34.13	84.96	13.41	16.51	47.54	101.47

Note: Cargo-tonnes were derived by the algebraic addition of figures for cargoes measured by weight (tonnes) and by volume (cubic metres).

Source: Bureau of Transport Economics, Information Paper, *Domestic Sea Freight Traffic Task by Commodity, 1973-74 to 1975-76*, June 1977.

For interstate passengers, origin and destination ports were known and the estimate of passenger-km was based on representative sailing distances between ports. These are listed in Appendix IV and are summarised in Table 6.2.

TABLE 6.2 - PASSENGER TASK PERFORMED BY COASTAL SHIPPING, 1975[a]

Units of Task	Type of Voyage		TOTAL
	Cruise	Interstate[b]	All Voyages
Passengers x 10^3	70.6	139.1	209.7
Passenger-km x 10^6	1.1	62.7	63.8

(a) Year ended 31st December. 1975 was the last year for which ABS collected statistics of interstate shipping travel.
(b) Passengers listed as 'in-transit' were excluded to avoid double counting. Of the interstate passenger movements, 94.3 per cent or 131 180 trips, were between Tasmania and mainland Australia.

Source: Bureau of Transport Economics estimates based on ABS, *Passenger Movements by Sea at Australian Ports, 1975*, January 1977. Ref 3405.0. Table 1.

Overseas Freight

Cargo movements between Australian ports and other nations are recorded by ABS[1]. Table 6.3 summarises these by grouping them into major geographical areas. Further details for individual countries, commodities, or individual Australian ports, are given by ABS[1][2][3].

(1) ABS, *Overseas and Coastal Shipping 1975-76*, January 1977. Ref 9207.0, Table 3.
(2) ABS, *Outward Overseas Cargo, 1975-76*, September 1977. Ref 9206.0.
(3) ABS, *Exports by Mode of Transport, Year Ended June 1976*, August 19976. Ref. 5415.0.

TABLE 6.3 - CARGO MOVEMENTS PERFORMED BY OVERSEAS SHIPPING, 1975-76

(cargo-tonnes x 10^6)

Region	Imported to Australia			Exported from Australia		
	Liners	Tramps, Bulkships and Tankers	All Vessels	Liners	Tramps, Bulkships and Tankers	All Vessels
North America & Hawaiian Islands	1.40	1.62	3.02	0.73	5.36	6.09
South America	0.02	-	0.02	0.04	0.48	0.52
Europe (incl USSR)	2.58	0.66	3.24	1.76	29.66	31.42
Africa	0.12	0.11	0.24	0.29	1.62	1.91
Eastern Asia	2.30	3.41	5.71	1.46	107.95	109.41
Other Asia	0.69	11.53	12.22	1.23	5.29	6.52
Papua NG, New Zealand, Pacific Is	0.75	1.04	1.79	1.25	1.48	2.73
Indian Ocean, Antarctic Area	-	0.65	0.65	-	0.02	0.02
TOTAL	7.87	19.02	26.89	6.76	151.87	158.62

Note: Cargo-tonnes were derived by the algebraic addition of figures for cargoes measured by weight (tonnes) and by volume (cubic metres).

Source: ABS, *Overseas and Coastal Shipping, 1975-76*, January 1977. Ref 9207.0, Table 3.

Estimates of tonne-km performed were prepared for this study by choosing representative sea distances between Australia and each geographical region, then multiplying them by the corresponding tonnage figures. The estimates are shown in Table 6.4. The representative distances are listed in Appendix IV. This procedure is only approximate, since the representative route for each region is necessarily only an average of many individual shipping routes between Australia and the many ports in that region. The accuracy of the tonne-km estimates could be improved by further dissecting cargo movements on a nation to nation basis, or even between individual ports. An exhaustive analysis would be required to extract this level of detail and this is considered to be beyond the scope of this analysis.

An analysis of cargo totals by commodity is given in Table 6.5. On a tonnage basis, the greatest proportion of imports was due to crude oil and refined petroleum, which together made up 42 per cent of the total. Amongst the commodities exported, the high proportion of bulk freight, particularly iron ore and coal, is clearly seen. The tonnage totals given in this table differ slightly from those in Table 6.3. This is due to the separate sources of data used for each.

Overseas Passenger

International passenger arrivals and departures by sea are published by the ABS(1). In Table 6.6, these are summarised in terms of major world regions. The corresponding figures for passenger-km were estimated in a similar way to overseas freight, by choosing representative sea distances for each region. These were multiplied by the passenger totals to give a figure for passenger-km for each region. The representative distances are listed in Appendix IV.

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(1) ABS, *Overseas Arrivals and Departures, 1976*, January 1978. Ref 3404.0, Table 1.

TABLE 6.4 - ESTIMATED FREIGHT TASK PERFORMED BY OVERSEAS SHIPPING, 1975-76

(Cargo tonne-km x 10^9)

Region	Imported to Australia			Exported from Australia		
	Liners	Tramps, Bulkships and Tankers	All Vessels	Liners	Tramps, Bulkships and Tankers	All Vessels
North America & Hawaiian Islands	25.26	29.35	54.61	13.16	96.86	110.01
South America	0.21	-	0.21	0.49	5.60	6.09
Europe (incl USSR)	52.69	13.46	66.16	35.86	522.87	558.73
Africa	1.37	1.25	2.62	3.17	17.98	21.14
Eastern Asia	21.05	31.17	52.22	13.33	987.74	1 001.07
Other Asia	8.96	149.31	158.28	15.94	68.53	84.47
Papua NG, New Zealand, Pacific Is	2.83	3.91	6.74	4.72	5.58	10.30
Indian Ocean, Antarctic Area	-	0.28	0.28	-	0.07	0.07
TOTAL	112.38	228.72	341.11	86.66	1 705.24	1 791.89

Source: Bureau of Transport Economics estimates based on ABS, *Overseas and Coastal Shipping 1975-76*, January 1977, Ref 9207.0, Table 3.

TABLE 6.5 - IMPORTS AND EXPORTS OF COMMODITIES THROUGH AUSTRALIAN PORTS, 1975-76

(Cargo tonnes x 10^6)

Imported to Australia		Exported from Australia	
Crude Oil	8.66	Iron Ore	80.37
Refined petroleum	4.24	Coal and coke	30.81
Vehicles and machinery	3.66	Other minerals	19.21
Chemicals	2.22	Grains	11.23
Phosphate and sulphur	1.80	Iron and steel[a]	3.94
Cement	1.59	Petroleum products	3.17
Timber	1.00	Forestry products	3.01
Paper and pulp	0.87	Sugar and molasses	2.25
Other specific commodities	1.41	Other agricultural products	2.14
General cargo	5.02	Chemicals	0.32
		Other specific commodities	0.82
		General cargo	5.35
TOTAL[b]	30.48	TOTAL[b]	162.61

(a) Includes vehicles and machinery.
(b) These totals disagree slightly with those from Table 6.3, reflecting the differing data sources. figures in Table 6.3 were compiled by ABS from Customs returns submitted by the shipping companies. The above table is derived directly from port authority statistics.

Source: Bureau of Transport Economics, *Australian Sea Freight Movements, 1975-76*, AGPS, Canberra, 1977.

TABLE 6.6 - ESTIMATED PASSENGER TASK PERFORMED BY OVERSEAS SHIPPING, 1975-76

Region	Into Australia		Out of Australia		TOTAL	
	Pass x 10^3	Pass-km x 10^6	Pass x 10^3	Pass-km x 10^6	Pass x 10^3	Pass-km x 10^6
Africa	2.37	26.7	0.26	2.9	2.63	29.6
America	2.30	42.9	3.00	56.0	5.30	98.9
Asia	14.20	101.4	12.01	85.7	26.21	187.1
Europe-Mediterranean Area	4.37	73.0	5.63	94.1	10.00	167.1
Europe-Other	11.19	228.4	11.21	228.9	22.40	457.3
Oceania	7.45	17.6	6.08	14.3	13.53	31.9
Not stated	4.08	51.7	3.90	49.4	7.98	101.1
TOTAL	45.96	541.7	42.09	531.3	88.05	1 073.0

Source: Passengers totals - based on ABS, *Overseas Arrivals and Departires*, unpublished information. Passenger-km: Bureau of Transport Economics estimates.

Summary

The preceding tables in this section are summarised in Table 6.7 below, which sets out the respective contributions of coastal and overseas operations towards the overall shipping task.

TABLE 6.7 - SUMMARY OF THE TASK PERFORMED BY SHIPPING, AUSTRALIA, 1975-76

Units of Task	Area of Operation		TOTAL
	Coastal	Overseas	All Areas
Passengers x 10^3	209.7[a]	88.1	297.8
Passenger-km x 10^9	0.064[a]	1.073	1.137
Freight: cargo-tonnes x 10^6	47.54	185.51	233.05
Freight: tonne-km x 10^9	101.47	2 132.99	2 234.47

(a) Year ended 31 December 1975.

Source: Derived from Tables 6.1, 6.2, 6.3, 6.4 and 6.6.

DIRECT ENERGY CONSUMPTION

Aggregate Fuel Consumption by Shipping

Since virtually all direct energy for shipping is provided by liquid fuels, account need only be taken of liquid fuels in the consideration of the energy used by shipping. The total bunkers uplifted in Australia by all categories of marine craft are recorded and published by the Department of National Development. They are shown in Table 6.8 below. These include fuels used by the Navy, and after adjusting them accordingly(1), the totals attributed to non-military craft are obtained.

The totals thus obtained include all liquid fuel use by trading and non-trading vessels. The latter would include fishing vessels, tugs, dredges, and official vessels. They would also include some portion of fuels used by privately owned motor driven craft, although some such craft simply utilise motor spirit or automotive distillate purchased from retail outlets on shore.

The contributions of non-trading and private craft to the total consumption of bunker fuels are not known, and for this analysis it is assumed that all non-military bunker fuels can be attributed to the trading fleet. The error in making this assumption is likely to be small, since the fuel use by non-trading vessels would be small relative to the total.

To summarise, the consumption of all bunker fuels for non-military purposes was attributed to the trading fleet. Table 6.8 shows that in 1975-76 this totalled 86.65 PJ, which represented all bunkers consumed by the coastal trading fleet and some proportion of bunkers consumed by overseas vessels(2). This latter proportion is unknown, although it has been suggested(3) that overseas vessels on Australian routes, in a similar way to international aircraft, uplift most of their fuel from overseas ports. This is principally because local bunker prices are pitched at world parity levels, so that overseas bunkering may be cheaper after taking into account their greater economies of scale. There is no known published information which can be used to dissect the total fuel

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(1) Based on information supplied by the Department of Defence, Canberra.
(2) 1 Petajoule = 10^{15} Joule.
(3) Based on information supplied by the Department of Transport, Sea Transport Policy Division.

TABLE 6.8 - SHIPS' BUNKER FUELS UPLIFTED IN AUSTRALIA, 1975-76

Fuel Type	Including Military Use	Excluding Military Use		
	(ML)	(ML)	(tonnes x 10^3)	(PJ)[a]
Automotive distillate	117.78	117.78	98.48	4.51
Industrial diesel fuel	374.38	300.18	254.17	11.59
Fuel Oil	1 822.08	1 732.38	1 610.02	70.55
TOTAL	-	-	1 962.67	86.65

(a) Energy conversion factors used were:

Automotive Distillate : 38.3 MJ/L
Industrial Diesel Fuel: 38.6 MJ/L
Fuel Oil : 40.7 MJ/L.

Source: Department of National Resources, *Petroleum Statistics*, Fiscal 1976-77, Melbourne, 1977, and information supplied by the Department of Defence, Canberra.
Energy conversion rates were obtained from: Department of National Development, *End Use Analysis of Primary Fuels Demand, Australia, 1973-74 to 1986-87*, Canberra, 1978.

consumption between coastal and overseas traffic, or between passenger and freight operations. Thus the analysis in the remainder of this chapter is based on estimates only.

Passenger and Freight

The relative tasks performed by passenger and freight shipping can be compared by referring to Table 6.7. In order to estimate their corresponding direct energy expenditures, it was assumed, after an examination of the literature, that the performance of 1 passenger-km would require about the same propulsion energy as 15 cargo tonne-km. Under this assumption the direct energy consumption attributable to the passenger task would be less than 1 per cent of that for the freight task, for both coastal and overseas shipping. This suggests that it is reasonable to regard the direct energy consumption of passenger shipping to be a negligible portion of the total direct energy for shipping. Hence, the energy value of all bunker fuels has been attributed to freight shipping.

Coastal and Overseas

The division of total bunker usage between coastal and overseas vessels in 1975-76 was made by estimating the total use of fuels by coastal vessels. This was based on operational statistics for a cross-section of the Australian trading fleet. The procedure is explained fully in Appendix IV. The extent of local bunkering by overseas ships was inferred by subtracting from the total for all ships the estimate for the coastal fleet. The results are expressed in Table 6.9.

As stated earlier in this chapter, the extent of bunkering in overseas ports by vessels carrying Australian imports and exports was unknown, but it can be inferred from the likely direct energy intensiveness which would be achieved on average by ocean-going vessels. It was assumed that the overall direct energy intensiveness attained in performing the overseas freight task

TABLE 6.9 - ESTIMATED DIRECT ENERGY CONSUMPTION BY SHIPPING, 1975-76

(PJ)

Analysis	Coastal Shipping	Overseas Shipping			SUBTOTAL Uplifted in Australia	TOTAL
		Uplifted in Australia	Uplifted outside Australia	SUBTOTAL Overseas Shipping		
Energy equivalent	25.1	61.5	365.5	427.0	86.7	452.2
Proportion of subtotal uplifted in Australia (per cent)	(29)	(71)	-	-	(100)	-
Proportion of total (per cent)	(6)	(14)	(81)	(95)	(19)	(100)

Source: Bureau of Transport Economics estimates.

would be in the range 0.10-0.30 MJ per tonne-km. The lower end of the range represents the typical performance of a supertanker, while the higher end is nearer that of a medium size freighter. Thomas[1] quoted a figure of 0.15 MJ per tonne-km for a supertanker (1972), although the basis of his estimate is not known. A value of 0.2 MJ per tonne-km was adopted to represent the average direct energy intensiveness of overseas shipping. when this value was multiplied by the total overseas (import and export) shipping task, given in Table 6.7, a figure of 427 PJ was derived for the corresponding direct energy consumption. It is emphasised that this value represents an order-of-magnitude estimate. If this estimate is accepted, then these bunkers uplifted locally by overseas vessels represented 14 per cent of the total direct energy expenditure on the international shipping task.

DIRECT ENERGY INTENSIVENESS

Coastal Shipping

For coastal shipping, direct energy intensiveness was calculated by dividing the total task (derived from Table 6.7) into the direct energy consumption (derived from Table 6.9). This gave a value of 0.25 MJ per cargo tonne-km. No data were found in the literature to check the validity of this estimate but because of the assumptions made in the analysis it can only be regarded as an order-of-magnitude value.

Since direct energy consumption relating to the coastal passenger task was assumed to be negligible, no estimate was made of the energy intensiveness of the coastal passenger task.

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(1) Thomas M.H., *Energy Utilisation in Transportation and Industry*, in *Western Australia's Energy Resources and Utilisation 1975-2000*, Institution of Engineers, Conference, Perth, October 1975, p.6.34.

Overseas Shipping

For overseas shipping the direct energy intensiveness has already been estimated at 0.2 MJ per cargo tonne-km, in deriving an estimate for the direct energy consumption. Again, the likely error in this estimate is not known, and it should be interpreted as an order-of-magnitude value only.

Since direct energy consumption relating to the overseas passenger task was assumed to be negligible, no estimate was made of the energy intensiveness of the overseas passenger task.

CHAPTER 7 - INDIRECT ENERGY CONSUMPTION

INTRODUCTION

The preceding chapters have described the task performed by each of the transport modes in Australia and the corresponding levels of direct or propulsion energy expended. To gain a picture of all energy flows within the transport sector, it is important to consider also the energy expended in those industrial, commercial and construction activities which are associated with transport. Such activities range from the refining of transport fuels to vehicle manufacture and repair, and the provision of fixed transport facilities. These are termed indirect energy usages in the transport sector. They are collectively referred to as the indirect component of transport energy consumption. The term 'indirect' is somewhat misleading since for any given activity much of the energy consumed by it may be a very direct input along with othe resources such as materials and labour. The term 'indirect energy' as used here, should be interpreted to simply mean energy usage associated with transport, other than that consumed for vehicle propulsion.

Indirect energy usages cannot be readily obtained from published energy statistics. This is due to two factors. Firstly, the major energy use by transport is undoubtedly its propulsion energy. Secondly, the propulsion energy is more readily identified and measured than the various indirect energy usages. The latter are difficult both to define and to measure, since in the published national energy statistics they are generally incorporated in the totals for various sectors of the economy. Data are not available in a sufficiently disaggregated form to enable those transport related energy usages to be easily extracted.

Occasional Paper 4[1] presented some brief comments on indirect energy and no separate analysis was attempted. The only relevant Australian study at that time appeared to be that by Beck[2], which examined energy inputs to the production of passenger cars in the year 1969. A further study reported was by Hirst and Herendeen[3] which attempted to identify all flows of energy associated with the production and use of automobiles in the USA in the year 1970.

Hirst and Herendeen concluded that the collective sum of indirect energy usages for cars was as high as 38 per cent of the total (direct and indirect) energy. Of this, the major constituent activities were; petrol refining and sales (14 per cent), highway construction and maintenance (7 per cent) and automobile manufacture (5.5 per cent).

Several more recent papers deal with aspects of energy usage associated with transport infrastructure. Berry and Fels[4] described a study similar to Beck's in which they conducted an energy analysis of the automobile manufacturing process. Perry and Volframs[5] identified the total energy consumption for road and rail transport in Tasmania in the year 1974. They make some assumptions which draw on both Berry and Fels and Hirst and Herendeen, as well as obtaining information from local transport and road authorities.

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(1) Clark N. and Associates, Occasional Paper 4, *op.cit.* Chapter 4.
(2) Beck J.A., *Energy Used in Producing Passenger Motor Cars*, Bulletin No 10, Department of Civil Engineering, University of Melbourne, September 1973.
(3) Hirst and Herendeen R., *Total Energy Demand for Automobiles*, SAE Paper 730065, International Automotive Engineering Congress, Detroit, January 1973.
(4) Berry R.S. and Fels M.F., *The Energy Cost of Automobiles*, Science and Public Affairs, December 1973.
(5) Perry N.R.F and Volframs A., *op.cit*.

Other related studies are Fels (urban transport in the US)[1], Pollard (air, rail and automobiles in the US)[2], Congressional Budget Office (urban transport in the US)[3] and Hirst (air transport in the US)[4]. In this latter paper, Hirst estimated that for commercial aviation in the US; the direct and indirect energy components respectively comprised 75 per cent and 25 per cent of total energy. Of the indirect component, the only significant single energy usage reported was fuel refining (16 per cent). Energy usage in producing aircraft, engines and parts, and in airport construction, comprised less than 3 per cent of the total for commercial aviation.

In the literature, no single study was found in which the indirect energy component was evaluated across all transport modes. For the modes considered, it appears that energy expenditures in fuel refining, vehicle manufacture and construction of facilities, when considered individually, were generally less than the direct energy consumption by an order of magnitude. Collectively, however, they constitute a significant proportion of the total energy, the proportion varying according to the transport mode.

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(1) Fels M.F., *Comparative Energy Costs of Urban Transportation Systems*, Transportation Research, vol 9, pp 297-308, 1975.
(2) Pollard J. et al, *A Summary of Opportunities to Conserve Transportation Energy*, Transportation Systems Center, Cambridge, Massachusetts, August 1975, NTIS publication PB-247 790.
(3) US Congressional Budget Office, *Urban Transportation and Energy; The Potential Savings of Different Modes*, Serial No 95-8, September 1977.
(4) Hirst E., *Direct and Indirect Energy Use for Commercial Aviation*, Transportation Research, Vol 8, 1974, p.430.

METHODS OF ENERGY ANALYSIS

In studies of energy usage there are two approaches which can be adopted. These are denoted Process Energy Analysis and Input-Output Energy Analysis[(1)].

Process energy analysis is more appropriate when the energy requirements of a particular activity are to be examined. A particular target product is chosen; this may be a good or a service. The energy requirements in the production process are then studied. Typically there will be fuel inputs to the process, along with other non-energy resource inputs. These latter are examined in turn and any energy inputs in their production are traced. This is continued until all significant energy inputs which contribute to the target product are identified. Extensive data are required for such an analysis and it is obviously more applicable to in-depth investigations of well defined activities. The above-mentioned studies by Beck and Berry and Fels are examples of this type of approach, where the automobile is the study target. Perry and Volframs applied a similar method to trace the energy inputs required to construct a unit length of road.

For input-output energy analysis, as for a general input-output table, the economy is disaggregated into sectors, each assumed to produce a unique good or service. The energy flows entering and leaving a sector are calculated by multiplying each product flow by its corresponding coefficient, expressed in energy units per dollar of output. In the US the development of appropriate coefficients is relatively recent. Hirst and Herendeen's paper is an example of this type of approach. For Australia, the appropriate coefficients have yet to be developed and it is

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(1) Bullard C.W. et al, *Energy Analysis: Handbook for Combining Process and Input-Output Analysis*, ERDA, publication 77-61, October 1976.

doubtful whether data is available to undertake a serious energy analysis of this type for a given sector such as transport.

DEFINITION OF INDIRECT ENERGY CONSUMPTION

From the literature it is clear that indirect energy usages fall into three general categories, representing three principal sectors of economic activity, which are as follows:

- manufacture, maintenance and repair of transport vehicles and parts;

- refining and retail sales delivery of transport fuels and lubricants; and

- construction, maintenance and operation of fixed transport facilities.

In some areas there are difficulties in choosing a clear demarcation between energy usage which is attributable to the transport sector or to other sectors. In the vehicle manufacturing industry, for example, energy expended in vehicle construction and in producing vehicle components can be readily associated with the vehicle as an end product. There is a chain of other energy consuming activities, such as the production of equipment used by the vehicle manufacturers, which become successively more distant from the transport application alone. It is necessary to decide at what point the energy inputs to these activities can be assumed to make a negligible contribution to the product of interest, in this case the motor vehicle. In the estimates discussed below, the scope of the analysis was restricted to energy used in producing the end product, or in processing the input materials.

The boundaries of energy accounting must also allow for the energy content of materials and equipment which is imported or exported. For example, when a vehicle is manufactured overseas and imported into Australia, energy used in its construction is expended in the country of origin, although the energy cost is met indirectly by the Australian purchaser of the vehicle. In an energy analysis the simplest approach is to account only for that energy which has been expended within Australia. This approach therefore excludes the energy content of imported vehicles and equipment, but includes energy expended in Australia in producing vehicles and equipment which may subsequently be exported. The choice of boundaries for energy analysis will clearly depend upon the objectives of any given study.

A degree of double counting is inherent in estimates of indirect energy consumption. The energy used to propel vehicles involved in the abovementioned areas of economic activity would also be accounted for in estimates of direct energy consumption. Thus estimates of indirect energy consumption represent over estimates to the extent that double counting has occurred.

ESTIMATION OF INDIRECT ENERGY CONSUMPTION

The purpose of this section is to indicate in broad terms the magnitude of indirect energy consumption associated with transport for each of the three principal sectors listed above. Where applicable, energy usage is apportioned amongst the transport modes, and some indication of the likely fuel mix is given.

So that estimates may be readily updated in the future, they have been based as far as possible upon published information which is issued on a regular or semi-regular basis.

Transport Vehicles and Parts

Data for fuels and electricity consumed in the vehicle industry during 1975-76 are published by the ABS[1]. These data are summarised in Table 7.1.

The energy sources listed by the ABS are a mixture of primary and secondary fuels. Coal and liquid fuels are primary fuel inputs whereas electricity, coke, briquettes and town gas are all secondary fuels. To be strictly correct, the energy wastage in deriving these secondary fuels should be included in the analysis to obtain a true primary fuel total. Since conversion efficiencies were not known, it was decided to list them in Table 7.1, in the form used by the vehicle manufacturing sector. In this form the amount of electricity used in vehicle manufacture can be readily seen in its true perspective.

In Table 7.1 a total of 6.90 PJ is attributed to vehicle construction and assembly[2]. This estimate does not include the energy expended by other supplier industries in the extraction and processing of materials for vehicle components. This cannot be derived from the same data source, but its magnitude can be inferred from previous studies of energy usage in vehicle manufacture.

Fels[3] has analysed energy usage in producing different urban vehicles in the US, including cars, urban buses and rapid rail cars. Fels found that the energy consumed was a direct function of vehicle mass, and assumed that the ratio of material process energy to construction and assembly energy could be regarded as constant across all types of urban vehicles. Its numerical value was taken as 2.8.

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(1) ABS, *Manufacturing Establishments: Details of Operations by Industry Class, Australia, 1974-75*, Canberra, 1977, Ref 8203.0 Table 8.
(2) 1 Petajoule = 10^{15} Joule.
(3) Fels M.F., *op.cit.*, Table 3.

TABLE 7.1 - SUMMARY OF ENERGY CONSUMPTION IN THE CONSTRUCTION AND ASSEMBLY OF TRANSPORT VEHICLES, 1975-76

(PJ)

Industry	Fuel Type				TOTAL	(per cent)
	Electricity	Solid(a)	Liquid(b)	Gas(c)		
Motor Vehicles & Parts	2.05	0.68	1.16	0.43	4.32	(62)
Ship & Boat Building and Repair	0.32	0.01	0.33	-	0.66	(10)
Locomotives & Rolling Stock Building and Repair	0.27	0.19	0.53	0.02	1.01	(15)
Aircraft Building and Repair	0.22	0.01	0.60	0.01	0.84	(12)
Transport Equipment nec	0.03	-	0.04	-	0.07	(1)
TOTAL	2.89	0.89	2.66	0.46	6.90	(100)
(per cent)	(42)	(13)	(39)	(6)	(100)	

Notes: Any differences in summation of columns are due to rounding. The following energy conversion rates were assumed:

Electricity: 7.52×10^{-3} \$/MJ
Solid: 25 GJ/tonne
Liquid: 1.2 L/kg; 44 GJ/tonne
Gas: 7.52×10^{-3} \$/MJ.

(a) Black and brown coal, briquettes and coke.
(b) Light oils, diesel fuel and fuel oils.
(c) Town gas and other fuels.
(d) nec = 'not elsewhere counted'.

Source: ABS, *Manufacturing Establishments: Details of Operations by Industry Class, Australia, 1975-76*, Canberra, 1977, Ref No 8203.0, Table 8. Energy conversion rates for solid and liquid fuels were taken from Department of National Development, *End Use Analysis of Primary Fuels Demand Australia, 1973-74 to 1986-87*, Canberra, 1978. Electricity conversion rate was taken from Electricity Supply Association of Australia, *The Electricity Supply Industry in Australia 1975-76*, Melbourne, April 1977.
Gas conversion rate was assumed to be the same as for electricity.

Beck[1] examined the production of Australian cars in 1969 and from his paper it is apparent that material process energy was two to three times greater than energy consumed in construction and assembly. This is in agreement with the assumption made by Fels. Beck simplified his analysis by including only metallic materials in his estimate of material process energy, since metals were assumed to form about 80 per cent of the mass of an average car. Plastics and aluminium require much more process energy per unit mass than steel but the proportion of these materials in cars at present is quite low[2]. The energy content of other materials was assumed to be negligible. Since about 70 per cent of the car mass is accounted for by ferrous components, nearly all of the material process energy involved in car production can be assumed to be expended in the iron and steel industry. Table 7.2 shows the use of fuels in iron and steel production.

TABLE 7.2 - PROPORTIONAL CONSUMPTION OF FUELS BY THE IRON & STEEL (BASIC PRODUCTS) INDUSTRY, 1975-76

(per cent)

Fuel Type				TOTAL
Electricity	Solid	Liquid	Gas	All Fuels[a]
19	25	55	1	100

(a) Equivalent to 62.4 PJ.

Source: Derived from ABS, *Manufacturing Establishments, Details of Operations by Industry Class, Australia, 1974-75*, Canberra 1977, Table 8.

(1) Beck J.A., *op.cit.*, p.14.
(2) Watson H.C., *Energy Usage in the Vehicle Life Cycle*, presented at the 'SAE - Australia's Policy on Automotive Energy' Seminar held in Melbourne, May 3, and Adelaide, July 5, 1979, Table B.2.

Drawing on these studies it was assumed that the ratio of material process energy to construction and assembly energy is essentially constant across all types of vehicles. The magnitude of this ratio was assumed to be 2.5 being the mean of the factors 2 and 3 mentioned in the previous paragraph. The material process energy was estimated from the known values for construction and assembly energy, by multiplying the right hand column of Table 7.1 by 2.5. The results are displayed in the right hand column of Table 7.3.

Most of the materials process energy associated with transport vehicles has been assumed to relate to ferrous components. While true for most industry categories, it is not true of the aircraft industry, for example, but it is considered that the procedure followed would give a conservative estimate for the aircraft sector. An indication of the mix of fuels used in the transport industry can therefore be obtained by assuming that the proportions of different types of energy used in the iron and steel industry in 1975-76 were the same as those in the transport vehicle industry for the same year. These proportions are shown in Table 7.2, and comprise electricity (19 per cent), solid fuels (25 per cent), liquid fuels (55 per cent) and gaseous fuels (1 per cent). The rows in Table 7.3 have been filled in by apportioning each entry in the right hand column across the fuels in these proportions. On the top row, for example, 2.05 PJ was derived as 19 per cent of 10.80 PJ, 2.70 PJ is 25 per cent of 10.80 PJ, and so on.

The energy usage associated with vehicle maintenance and repair is now considered. From Tables 7.1 and 7.3 it is seen that the ABS industry categories listed on the left hand side already include 'repair' for the ship, railway and aircraft industries. If these are taken to also include maintenance, then the maintenance and repair energy for these three modes is accounted for in the right hand column of Table 7.1. For motor vehicles a separate estimate must be made.

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TABLE 7.3 - ESTIMATED ENERGY CONSUMPTION IN PRODUCING MATERIALS FOR THE TRANSPORT VEHICLE INDUSTRY, 1975-76

(PJ)

Industry	Fuel Type				TOTAL	(per cent)
	Electricity	Solid	Liquid	Gas		
Motor Vehicles & Parts	2.05	2.70	5.94	0.11	10.80	(62)
Ship & Boat Building and Repair	0.31	0.41	0.91	0.02	1.65	(10)
Locomotives & Rolling Stock Building and Repair	0.48	0.64	1.39	0.02	2.53	(15)
Aircraft Building and Repair	0.40	0.53	1.15	0.02	2.10	(12)
Transport Equipment nec[(a)]	0.03	0.05	0.10	0.00	0.18	(1)
TOTAL	3.27	4.33	9.49	0.17	17.26	(100)
(per cent)	(19)	(25)	(55)	(1)	(100)	

(a) nec = 'not elsewhere counted'.

Source: Bureau of Transport Economics estimates.

Referring again to Hirst and Herendeen[1], energy consumption associated with car retail sales, repairs, maintenance, tyre manufacturing and sales, and insurance, was estimated to be about 1.4 times greater than the consumption in car manufacture. Using this as an indicative ratio and applying it to all road vehicles in Australia, an estimate of 21.17 PJ was obtained by multiplying by 1.4 the sum of data in the first row of the right hand columns of Tables 7.1 and 7.3, ((4.32 + 10.80) PJ). This provided an order of magnitude estimate for energy expenditure within the above activities for motor vehicles in Australia. This estimate was inserted into Table 7.4, which summarises the results of this section. The total energy consumption involved in the manufacture, maintenance and repair of transport vehicles was thus estimated to be 45.33 PJ of which 80 per cent was attributed to motor vehicles. Each of the other transport modes accounted for less than 10 per cent of the total.

Finally, an indicative mix of fuel sources for the vehicle industry is shown in Table 7.5. Rows 1 and 2 of the table were extracted from Tables 7.1 and 7.3 respectively. In row 3, the maintenance and repair energy for motor vehicles was allocated entirely to electricity. This is reasonable, since electricity would form the major source of light, heat and power for garages and service depots, as well as for vehicle and tyre sales outlets and insurance. If this fuel mix is accepted, it is seen that elecricity was the dominant energy source, providing 60 per cent of the total, followed by liquid fuels with 27 per cent. However, if the motor vehicle maintenance and repair energy was excluded and the vehicle construction industry only was considered, (the sum of rows 1 and 2 of Table 7.5), then liquid fuels would have provided the largest share at 50 per cent of 24.16 PJ, followed by solid fuels with 22 per cent.

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(1) Hirst E. and Herendeen R., *op.cit.*, Table 3.

TABLE 7.4 - SUMMARY OF ENERGY CONSUMPTION IN TRANSPORT VEHICLE AND PARTS MANUFACTURE, MAINTENANCE AND REPAIR, 1975-76

(PJ)

Industry	Construction and Assembly[a]	Production of Input Materials[b]	Maintenance and Repair	TOTAL All Activities	(per cent)
Motor Vehicles	4.32	10.80	21.17	36.29	(80)
Ship & Boat	0.66	1.65	-	2.31	(5)
Locomotive & Rolling Stock	1.01	2.53	-	3.54	(8)
Aircraft	0.84	2.10	-	2.94	(6)
Transport Equipment nec[c]	0.07	0.18	-	0.25	(1)
TOTAL	6.90	17.26	21.17	45.33	(100)

(a) Already includes Maintenance and Repair for all categories except Motor Vehicles.
(b) Estimated at 2.5 times column 1 (see text).
(c) nec = 'not elsewhere counted'.

Source: Bureau of Transport Economics estimates.

TABLE 7.5 - SUMMARY BY FUEL TYPE OF ENERGY CONSUMPTION IN TRANSPORT VEHICLE AND PARTS MANUFACTURE, MAINTENANCE AND REPAIR, 1975-76

(PJ)

Industry	Fuel Type				TOTAL	(per cent)
	Electricity	Solid	Liquid	Gas		
Construction & Assembly	2.89	0.89	2.66	0.46	6.90	(15)
Production of Input Materials	3.27	4.33	9.49	0.17	17.26	(38)
Maintenance & Repair (Motor Vehicles only)	21.17	-	-	-	21.17	(47)
TOTAL	27.33	5.22	12.15	0.63	45.33	(100)
(per cent)	(60)	(12)	(27)	(1)	(100)	

Source: Bureau of Transport Economics estimates.

The estimates of indirect energy consumption presented in Table 7.5 relate to the year 1975-76. Estimates have also been made for the year 1974-75 using the same assumptions as made above. These were based on data on Manufacturing Establishments published by ABS for 1974-75, and the energy conversion rates of Table 7.1. These estimates are mentioned to illustrate the year-to-year variation in these figures. For 1974-75 the total energy consumption for transport vehicle and parts manufacture, maintenance and repair was 52.50 PJ, which is 15 per cent higher than the figure for 1975-76. The corresponding figure for motor vehicles and parts was 17 per cent higher in 1974-75 (at 42.50 PJ) than the 1975-76 figure of 36.29 PJ (Table 7.4 refers).

While these changes may reflect differences within the transport vehicle industry between the two years, it may also be due to differences in the activity and structure of the iron and steel (basic products) industry between the years, in which the foregoing estimates have been based. It is not possible to fully explain the difference with the available data.

Returning to the year 1975-76, the figure of 45.33 PJ for the indirect energy used in transport vehicle and parts manufacture, maintenance and repair (Table 7.4 refers) was equivalent to 7 per cent of both total domestic transport energy consumption and total national transport energy consumption. The corresponding figure for motor vehicles and parts (36.29 PJ) was also equivalent to 7 per cent of domestic transport energy consumption by the road mode (Tables 8.4 and 8.6 refer).

Transport Fuels and Lubricants

The total amount of crude oil in the world has been described in terms of 'reserves' and 'resources'[(1)]. Because of the

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(1) Resources for the Future Inc., *Oil and Gas Resources - Welcome to Uncertainty*, Resources, Washington DC, 58, 1978, p.2.

complexity of defining thse terms, it is not easy to determine the amount of crude oil actually 'available' for use as a starting point for measuring the energy potential. For this reason it is difficult and probably meaningless to apply a measure of 'efficiency' to the crude oil extraction process. For energy accounting purposes it is simpler although arbitrary to use the quantity of crude oil actually produced as the point of measurement of its energy potential.

At the petroleum refinery, crude oil feedstock is processed into fractions yielding a range of fuel and non-fuel products, from aviation gasoline and motor spirit at the higher end, down to fuel oil and bitumen. In this process certain intermediate products are produced to be re-used within the refinery itself, mainly for heating. A list of refinery inputs and products for Australia is given in Table 7.6.

Apart from crude oil and other feedstocks, refineries also consume electricity. In 1975-76, refinery electricity consumption totalled 1 PJ(1). Table 7.6 shows the total energy content of marketable fuel products, estimated at 1095 PJ or about 92 per cent of the energy potential of feedstock (1194 PJ). While some of the difference would be attributed to fuel consumed in the refinery and to losses through spillage and evaporation, some would also be contained in the energy of 'non-fuel' products, such as lubricating oil and bitumen, for which energy values are not conventionally published. The energy content of refinery fuels has been fully allocated to the transport sector following the approach used by Watson(2).

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(1) Consumption of electricity in the petroleum refining industry is given in ABS, *Manufacturing Establishments: Details of Industry by Class, Australia, 1975-76*, Canberra, 1977, Ref 8203.0, Table 8.

(2) Watson H.C., *op.cit.*

TABLE 7.6 - FUEL INPUTS AND PRODUCTS IN PETROLEUM REFINING, AUSTRALIA, 1975-76

Inputs and Products	(ML)	(PJ)	(PJ)	(Per cent)
Inputs:				
Crude oil and other feedstocks	33 542	1 194		
Electricity		1	1 195	100.0
SUBTOTAL - Inputs				
Marketable Products:				
Motor Spirit	12 501	434		
Automotive Distillate	5 987	229		
Fuel Oil	4 675	190		
Aviation Turbine Fuel	2 088	77		
Industrial Diesel Fuel	1 430	55		
Heating Oil	733	28		
LPG	672	18		
Bitumen	465	-		
Lubricating Oil Base Stock (a)	431	-		
Solvents (a)	211	-		
Lighting Kerosene	210	8		
Refinery Gas (foe) (b)	122	5		
Aviation Gasoline	37	1		
Power Kerosene	29	1		
Other Marketable Products	1 363	49		
SUBTOTAL				
Marketable Products	30 954		1 095	91.6
DIFFERENCE:				
SUBTOTAL Inputs - SUBTOTAL Products			100	8.4

(a) 'non fuel' products.
(b) foe = 'fuel oil equivalent'.

Sources: Electricity - ABS, *Manufacturing Establishments: Details of Industry by Class, Australia, 1975-76*, Canberra 1977, Table 8.
All Others - Department of National Resources, *Petroleum Statistics, Fiscal 1976-77*, Melbourne, 1977, and Australian Institute of Petroleum Ltd, *Oil and Australia*, 1977, Melbourne, 1977.

Watson[1] has estimated that the energy consumed in the delivery of petrol to retail sales outlets was equivalent to 0.15 per cent of petrol consumption by cars in 1974-75. Assuming that this proportion applied to the 687 PJ of transport fuels estimated to have been consumed by private, bulk and Government users in 1975-76 (Table 7.7 refers), the sales delivery energy for all fuels amounted to 1 PJ.

Turning from production to consumption of petroleum fuel products, this latter measured 1166 PJ[2] for 1975-76. This figure did not include consumption within refineries. Of all fuel products, only six were used to any significant extent as transport fuels, and the estimated share of each due to transport is shown in Table 7.7.

The use of lubricants by Australian transport is indicated in Table 7.8 and compared with the overall consumption for Australia. For transport usage the only published data available were those for Government railways, the remaining figures being estimates. The transport sector share of lubricant consumption based on these estimates amounted to about 53 per cent by volume of the total for 1975-76. By convention, the energy content of lubricants is not taken into account in energy studies and has been omitted from consideration in this report. However, it may be noted that Watson[3] derived an energy equivalence for lubricating oil consumed by passenger cars and derivatives during 1974-75. He obtained a value for the energy content of lubricating oil of 3 per cent of total (direct and indirect) energy consumption for the study period.

From the above discussion, the amount of energy accounted for by the refining and retail sales delivery of transport fuels

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(1) Watson H.C., *op.cit.*
(2) Department of National Resources, Petroleum Statistics, *op.cit.*, p.18.
(3) Watson H.C., *op.cit.*, Table 2.

TABLE 7.7 - TRANSPORT AND TOTAL CONSUMPTION OF SELECTED PETROLEUM FUEL PRODUCTS,[a] AUSTRALIA, 1975-76

Product	Consumption for Vehicle Propulsion	Total Consumption in Australia		Proportion of Consumption due to Transport
	(PJ)	(ML)	(PJ)	(per cent)
Aviation Gasoline	4	105	4	(100)
Aviation Turbine Fuel	61	1 845	68	(90)
Motor Spirit	453	13 260	462	(98)
Automotive Distillate	89	5 350	213	(42)
Industrial Diesel Fuel	11	1 872	75	(15)
Fuel Oil	71	6 330	253	(27)
TOTAL	687	-	1 085	(63)
TOTAL consumption of all petroleum fuel products		-	1 166	(59)

Note: Energy conversion factors used were those published by the Department of National Development.

(a) Uplifted in Australia.

Source: Transport Consumption - see earlier chapters. Tables 3.10, 4.9, 5.7, 6.8 and B.1.
Total Consumption - Department of National Resources, *Petroleum Statistics, Fiscal 1976-77*, Melbourne, 1977.

and lubricants is estimated at 101 PJ or 8.45 per cent of refinery production.

TABLE 7.8 - ESTIMATED CONSUMPTION OF LUBRICANTS BY TRANSPORT SECTOR, AUSTRALIA, 1975-76

Transport Mode	Volume (ML)	Volume (per cent)
Road[(a)]	145	(33)
Rail[(b)]	61	(14)
Sea[(c)]	17	(4)
Air[(d)]	9	(2)
SUB TOTAL - Transport	232	(53)
TOTAL Australia - All Sectors	436	(100)

(a) Estimated as 1 per cent of direct road fuel consumption.
(b) Estimated as 1 per cent of direct fuel consumption.
(c) Estimated as 0.5 per cent of direct fuel consumption.
(d) Uplifted in Australia.

Sources: Bureau of Transport Economics estimates, except for rail. ABS, *Rail, Bus and Air Transport, 1975-76*, Canberra 1977, Ref 14.21 (for rail).
Department of National Resources, *Petroleum Statistics, Fiscal 1976-77*, Melbourne 1977 (all sectors total).

Fixed Transport Facilities

The fixed facilities which form part of the transport system include roads, car parks, bridges, railway lines, terminals, ports, depots, and airports. Energy is consumed by vehicles and machinery engaged in construction and maintenance of these facilities and for heating, lighting and power during their operation. It is also expended in extracting and processing material inputs for construction, such as concrete, road metal, and steel rail-tracks. In published data of energy consumption for Australia, these energy uses are collected under more general activity headings such as Construction, Mining and Commerce. It is not possible to extract those energy usages which relate to transport.

An assessment has recently been made by Underwood[(1)] of the amount of indirect oil-based energy accounted for by road construction and maintenance in Australia. Underwood stated that road construction and maintenance operations account for between 2 and 3 per cent of liquid fuel used on the roads in Australia, with about half of this made up of bituminous products. After allowing for the use of bituminous products, this indicates that road construction and maintenance would account for between 1 and 1.5 per cent of the liquid fuel consumed by road vehicles.

Watson[(2)] has assessed the amount of oil - based and other energy accounted for by road construction and maintenance during 1974-75 and found that an amount of energy equivalent to 1.9 per cent of the total direct and indirect liquid fuel energy consumed by passenger cars and derivatives was accounted for in this way. This amount was equivalent to 2.4 per cent of the direct energy consumption in that year by these vehicles.

Table 3.10 indicates that the energy consumed by all road vehicles in 1975-76 was 513 PJ, and the energy consumed by passenger cars and derivatives was 403 PJ. Applying the data of Underwood and Watson to these data, the higher estimate of the energy required for road construction in 1975-76 is 10 PJ (2.4 per cent of 403 PJ).

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(1) Underwood R.T., *Energy Needs: Planning for the Future - Road Building*, Thirty-fifth Conference of Municipal Engineers, Melbourne, March 19 and 20, 1979, p.1.
(2) Watson H.C., *op.cit.*, Table 2.

Road transport infrastructure would be expected to cover mainly the construction and maintenance of the road network, as well as car parking facilities, etc. Rail system infrastructure would include in addition to the rail track, terminals, storage areas, and vehicle construction and repair facilities. The infrastructure associated with the air and sea modes would be concentrated in runways, terminals, storage areas, construction and repair facilities, and so on.

In order to overcome the complexity of analysing the infrastructure associated with modes other than road, it has been assumed that indirect energy was expended on each mode in proportion to the Gross Fixed Capital Expenditure on each mode for the study year.

Table 7.9 indicates that the ratio of Gross Fixed Capital Expenditure (GFCE) on roads in 1975-76 was 71 per cent of total GFCE on all modes. Thus the figure of 10 PJ representing the amount of indirect oil-based national transport energy consumption accounted for by road construction and maintenance has been increased by (100/71) to account for the oil-based indirect energy associated with the provision and maintenance of transport infrastructure in general. The amount of oil-based direct national transport energy accounted for by all infrastructure was thus assumed to be 14 PJ.

There is no information available to estimate the amount of non oil-based indirect energy consumption relating to the provision of infrastructure in 1975-76.

<u>Summary of Indirect Energy Consumption</u>

Table 7.10 sets out estimates of oil-based only and total indirect energy of transport modes for 1975-76. It will be noted that there was an unknown amount of non oil-based energy associated with the provision of transport infrastructure in that year. As stated earlier in this chapter, a degree of double

counting is involved in estimating indirect energy consumption, due to the inclusion of vehicle propulsion energy in the estimates along with energy used by off-road vehicles.

The estimates discussed above indicate that indirect energy is of considerably less magnitude than was indicated in Occasional Paper 4.

TABLE 7.9 - GROSS FIXED CAPITAL EXPENDITURE IN TRANSPORT (ALL PUBLIC AUTHORITIES) AUSTRALIA, 1975-76

Transport Mode	Value	
	($ million)	(per cent)
Road	1 351	(71)
Rail	321	(17)
Air	88	(5)
Sea	137	(7)
TOTAL	1 897	(100)

Source: ABS, *Australian National Accounts: National Income and Expenditure 1976-77*, Canberra, 1978. Ref 5204.0 Table 57.

TABLE 7.10 - ESTIMATED CONSUMPTION OF INDIRECT ENERGY BY ALL TRANSPORT MODES, AUSTRALIA, 1975-76

(PJ)

Category	Oil-based only	TOTAL
Vehicle manufacture, maintenance and repair	12.2	45.3
Fuel manufacture	100.0	100.0
Fuel delivery	1.0	1.0
Infrastructure construction and maintenance	14.0 (b)	14.0 (a) (b)
TOTAL	127.2 (b)	160.3 (a) (b)

(a) Excludes an unknown amount of non oil-based energy relating to construction and maintenance of infrastructure.
(b) Includes an unknown amount of double counting of direct energy.

Source: Tables 7.5, 7.6 and text of Chapter 7.

CHAPTER 8 - OVERALL FINDINGS

INTRODUCTION

This chapter summarises the task and energy consumption information analysed in previous chapters and assembles it in a form which permits an appraisal of the contribution of each transport mode to the Australian transport scene. Data on pipelines and ferries were not included in this chapter. Pipelines are discussed separately in Appendix VI. The contribution of ferries was considered too small to warrant inclusion; they are mentioned briefly in Appendix IV.

SUMMARY OF THE TRANSPORT TASK

Domestic Passenger Task

The domestic passenger task for 1975-76 is summarised in Table 8.1. It can be seen that road transport dominated this part of the transport task, accounting for about 90 per cent of passenger-km. There was about an equal division of the passenger task between urban and non-urban areas for road vehicles and for all transport modes.

The passenger task of utilities and panel vans has been treated differently in this report compared to Occasional Paper 4. These vehicles obviously perform a transport task in conveying their occupants as well as in conveying freight. In this paper a portion of this occupant task has been assessed as contributing to the overall domestic passenger task. In Occasional Paper 4, utilities and panel vans were assumed to make a negligible contribution to the passenger task.

Domestic Freight Task

This is set out in Table 8.2. Coastal shipping is seen to have been the largest contributor in 1975-76 to the freight task at about 50 per cent, followed by rail which accounted for about 30 per cent. The road mode was smaller again, having accounted for only about 20 per cent of the freight task. Air freight made a negligible contribution in comparative terms.

TABLE 8.1 - SUMMARY OF ESTIMATED DOMESTIC PASSENGER TASK, 1975-76

(Passenger-km x 10^9)

Transport Mode	Urban	Non-Urban	TOTAL	(per cent)
Road				
Cars and Station Wagons	76.58	79.09	155.67	(81)
Motorcycles	1.03	0.75	1.78	(1)
Utilities and Panel Vans	na	na	9.23	(5)
Buses	3.97	3.62	7.59	(4)
SUB TOTAL - Road	81.58[a]	83.46[a]	174.27	(91)
Rail				
Trams	0.53	-	0.53	neg
Trains	5.76	2.40	8.16	(4)
SUB TOTAL - Rail	6.29	2.40	8.69	(5)
Air				
Domestic Airlines	-	7.66	7.66	(4)
General Aviation	-	0.40	0.40	neg
SUB TOTAL - Air	-	8.06	8.06	(4)
Sea, Coastal	-	0.06	0.06	neg
TOTAL	87.87[a]	93.98[a]	191.08	(100)

(a) Excludes utilities and panel vans.

Source: Tables 3.4, 4.2, 5.5 and 6.2 and text of Chapter 4.

TABLE 8.2 - SUMMARY OF ESTIMATED DOMESTIC FREIGHT TASK, 1975-76

(tonne-km x 10^9)

Transport Mode	Urban	Non-Urban	TOTAL	(per cent)
Road				
Utilities and Panel Vans	0.98	0.60	1.58	(1)
Trucks	12.12	23.00	35.12	(18)
Buses	neg	neg	neg	neg
SUB TOTAL - Road	13.10	23.60	36.70	(19)
Rail				
Government Trains	-	30.81	30.81	(16)
Non-Government Trains	-	26.35	26.35	(13)
SUB TOTAL - Rail	-	57.16	56.16	(29)
Air				
Domestic Airlines	-	0.11	0.11	neg
General Aviation	-	0.01	0.01	neg
SUB TOTAL - Air	-	0.12	0.12	neg
Sea, Coastal				
Interstate	-	84.96	84.96	(43)
Intrastate	-	16.51	16.51	(9)
SUB TOTAL - Sea	-	101.47	101.47	(52)
TOTAL	13.10	182.35	195.45	(100)

Source: Tables V.13, 4.3, 4.4, 5.5 and 6.1

It should be noted that Coastal Shipping has been divided into two sections - Interstate and Intrastate. In Occasional Paper 4, Coastal Shipping was treated as a single category.

International Transport Task

The international passenger and freight tasks for 1975-76 are set out in Table 8.3. These figures are the sum of inbound and outbound task totals. No attempt has been made to estimate a share of these tasks attributable to Australia, as was done in Occasional Paper 4. It can be seen that airlines dominated in the transport of passengers, while shipping accounted for almost all freight transport.

SUMMARY OF TRANSPORT ENERGY CONSUMPTION

Direct Energy Consumption - Domestic Transport

An analysis of the direct energy consumed by domestic transport which totalled 613 PJ in 1975-76 is set out in Table 8.4(1). Direct energy is defined as the energy used to propel or drive vehicles, as distinct from indirect energy which covers energy used for purposes other than propulsion. The Table shows that cars and station wagons consumed about 55 per cent of direct energy, while the road mode as a whole accounted for about 85 per cent of the total. The other modes, rail, air and sea each accounted for about 5 per cent of direct energy.

Direct Energy Consumption - International Transport

The direct energy consumed by international transport to and from Australia during 1975-76 has been analysed by location of fuel uplift as well as by mode in Table 8.5. The sea mode accounted for most of the direct energy used. However, of the total direct energy consumed by international transport travelling to or from Australia, probably about one sixth of the total was actually uplifted in Australia.

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(1) 1 Petajoule = 10^{15} Joule.

TABLE 8.3 - SUMMARY OF ESTIMATED INTERNATIONAL TRANSPORT TASK FOR AUSTRALIA, 1975-76

Transport Mode	Passenger		Freight	
	Pass $x\ 10^3$	Pass-km $x\ 10^9$	Tonnes Carried $x\ 10^6$	Tonne-km $x\ 10^9$
International Airlines	2 801.0	27.03	0.08	0.75
Overseas Shipping	88.1	1.07	185.51	2 132.99
TOTAL	2 889.1	28.10	185.59	2 133.74

Note: Figures given are the combined totals for inbound and outbound movements.

Source: Tables 5.2, 5.3 and 6.7.

TABLE 8.4 - SUMMARY OF ESTIMATED DIRECT ENERGY CONSUMPTION BY DOMESTIC TRANSPORT, 1975-76

(PJ)

Transport Mode	Passenger		Freight		TOTAL	(per cent)
	Urban	Non-urban	Urban	Non-urban		
Road						
Cars & Station Wagons	247.28	95.32	-	-	342.60	(56)
Motorcycles	2.24	1.11	-	-	3.35	(1)
Utilities & Panel Vans[a]	na	na	na	na	60.74	(10)
Trucks	-	-	48.40	50.79	99.19	(16)
Buses	5.09	2.07	neg	neg	7.16	(1)
SUB TOTAL - Road	254.61[b]	98.50[b]	48.40[b]	50.79[b]	513.04	(84)
Rail						
Trams	0.98	-	-	-	0.98	neg
Government Trains	10.84	1.95	-	17.51	30.30	(5)
Non-Government Trains	-	-	-	3.58	3.58	(1)
SUB TOTAL - Rail	11.82	1.95	-	21.09	34.86	(6)
Air						
Domestic Airlines	-	31.60	-	5.04	36.64	(6)
General Aviation	-	2.83	-	0.70	3.52	neg
SUB TOTAL - Air	-	34.43	-	5.74	40.16	(6)
Sea, Coastal	-	neg	-	25.10	25.10	(4)
TOTAL	266.43[b]	134.88[b]	48.40[b]	102.72[b]	613.16	(100)

(a) For utilities and panel vans, 24.88 PJ was attributed to the passenger transport task and 35.86 PJ to the freight transport task; 38.37 PJ were consumed in urban areas, and 22.37 PJ were accounted for in non-urban areas. Data are not available by task and area of operation.

(b) Excluding utilities and panel vans.

Source: Tables 3.12, 4.6, 4.8, 4.9, 5.8 and 6.9.

TABLE 8.5 - SUMMARY OF ESTIMATED DIRECT ENERGY CONSUMPTION BY INTERNATIONAL TRANSPORT, 1975-76

(PJ)

Location of Fuel	Mode		TOTAL
	Air (per cent)	Sea (per cent)	(per cent)
Within Australia	24.4[a] (30)	61.5[b] (14)	85.9 (17)
Outside Australia	57.8 (70)	365.5 (86)	423.3 (83)
TOTAL (per cent)	82.2 (100)	427.0 (100)	509.2 (100)

Note: 1 Petajoule = 10^{15} Joule.

(a) Assumed that energy relates entirely to passenger task.
(b) Assumed that energy relates entirely to freight task.

Source: Tables 5.8 and 6.9.

Contribution of Transport Modes to Direct National Transport Energy Consumption

The information contained in Tables 8.4 and 8.5 has been brought together in Table 8.6. This Table shows the contribution of each transport mode to direct fuel energy consumed by the national transport sector for 1975-76. National direct transport energy consumption was defined as the sum of domestic direct energy and that portion of international direct energy uplifted in Australia. This category is considered necessary because international direct energy uplifted in Australia must be either produced in Australia or else imported. Thus the transport energy concern in Australia is wider than concern for energy consumed by domestic transport only.

TABLE 8.6 - ESTIMATED CONTRIBUTION OF TRANSPORT MODES TO NATIONAL DIRECT TRANSPORT ENERGY CONSUMPTION, 1975-76

(per cent)

Transport Mode	Passenger		Freight		TOTAL
	Urban	Non-urban	Urban	Non-urban	
Road					
Cars & Station Wagons	35.4	13.6	-	-	49.0
Motorcycles	0.3	0.2			0.5
Utilities & Panel Vans[(a)]	na	na	na	na	8.7
Trucks	-	-	6.9	7.3	14.2
Buses	0.7	0.3	neg	neg	1.0
SUB TOTAL - Road	36.4[(b)]	14.1[(b)]	6.9[(b)]	7.3[(b)]	73.4
Rail					
Trams	0.1	-	-	-	0.1
Government Trains	1.6	0.3	-	2.5	4.3
Non-Government Trains	-	-	-	0.5	0.5
SUB TOTAL - Rail	1.7	0.3	-	3.0	5.0
Air, with Australia					
Domestic Airlines	-	4.5	-	0.7	5.2
General Aviation	-	0.4	-	0.1	0.5
SUB TOTAL - Air, within Australia	-	4.9	-	0.8	5.7
Air, International	-	3.5	-	neg	3.5
Sea, Coastal	-	neg	-	3.6	3.6
Sea, Overseas	-	neg	-	8.8	8.8
TOTAL	38.1[(b)]	22.8[(b)]	6.9[(b)]	23.5[(b)]	100.0

Note: National energy consumption is defined as the energy sum of domestic consumption and fuel uplifted in Australia by international transport (699.1 PJ).

(a) For utilities and panel vans, the urban/non-urban split was 5.5/3.2 (per cent). The passenger/freight split was 3.6/5.1 (per cent).

(b) Excludes utilities and panel vans.

Source: Tables 8.4 and 8.5.

Table 8.6 shows that cars and station wagons accounted for one half of national direct energy consumption during 1975-76. The remainder of the road mode accounted for a further quarter of national direct energy consumption. The other modes in order of significance were sea and air, with rail making the smallest contribution to national consumption.

Two thirds of national direct energy consumption related to passenger transport, and one third to freight transport.

Contribution of Oil Energy to Direct National Transport Energy Consumption

Almost all direct transport energy consumption is dependent on petroleum fuels. The exceptions are trams and electric and coal-fired trains.

In 1975-76, the direct energy consumption of these modes amounted to 10 PJ (Table 8.7 refers). This figure represented 1.4 per cent of estimated national direct transport energy consumption (699 PJ). Thus oil energy accounted for about 99 per cent of national direct transport energy consumption in 1975-76.

Energy Consumption per Vehicle-km

Table 8.8 shows the average amount of energy required to propel transport vehicles during 1975-76. This information has been prepared to permit assessment of the impact of large scale energy conservation programs or mobility constraints imposed on whole classes of vehicles. Calculations have been made for land-based vehicle classes only on the assumption that these classes would be the most greatly affected by energy conservation measures.

The data should be used with caution since the energy consumed by particular vehicle types or in particular transport operations may differ sharply from the modal average.

TABLE 8.7 - ESTIMATED CONTRIBUTION OF NON OIL-BASED FUELS TO NATIONAL CONSUMPTION OF DIRECT TRANSPORT ENERGY, 1975-76

(PJ)

Transport Mode	Energy Type		TOTAL
	Electricity[a]	Coal	All Fuels
Trams	0.98	-	0.98
Trains	8.66	0.06	8.72
TOTAL	9.64	0.06	9.70

Notes: Consumption of bagasse by sugar tramways has been ignored in this analysis.
1 Petajoule = 10^{15} Joule.

(a) Primary fuel equivalent.

Source: Tables 4.6 and 4.7.

TABLE 8.8 - SUMMARY OF ESTIMATED ENERGY CONSUMPTION PER VEHICLE-KM FOR LAND TRANSPORT MODES, 1975-76

(MJ/Vehicle-km)

Transport Mode	Area of Operation		MEAN
	Urban	Non-Urban	All Areas
Cars and Station Wagons	5	4	4
Motorcycles	2	2	2
Utilities and Panel Vans	6	4	5
Trucks	12	12	12
Buses	12	12	12
Trams	39	-	39
Trains[a]			
passenger	247	67	178
freight	-	224	224

Note: Caution should be used in using the above data to make comparison between modes.

(a) MJ per train-km.

Source: Tables 3.14, 4.11 and text of Chapter 4.

The Table shows that in average urban conditions cars and station wagons consumed about 40 per cent of the energy of trucks and buses in travelling one kilometre, and one-fiftieth of the energy of passenger trains. All modes used less energy in non-urban areas than in urban areas, with the largest reduction being for passenger trains.

Indirect Energy Consumption

Indirect energy consumption for 1975-76 was estimated at 160 PJ. This amount was equivalent to 26 per cent of direct domestic transport energy consumption and 23 per cent of direct national transport energy consumption. A total of 127 PJ (80 per cent) of indirect transport energy was estimated as being oil based.

SUMMARY OF DIRECT ENERGY INTENSIVENESS

Direct Energy Intensiveness - Domestic Transport

Table 8.9 contains estimates of direct energy intensiveness for 1975-76, which is defined as the ratio of the energy required to propel a class of vehicles to a measure of the transport task performed. Since different modes of transport undertake different tasks under different conditions, the use of energy intensiveness data for direct comparison between modes is dangerous.

Air travel used the greatest amount of energy to perform its passenger task while buses used the least amount of energy. There were orders of magnitude difference between the energy intensiveness of the different modes of freight transport. Non-government railways, comprising mainly the iron ore railways, had the lowest level of energy intensiveness, closely followed by coastal shipping and government railways. At the other extreme, utilities and panel vans and the air mode generally had very high levels of energy intensiveness.

TABLE 8.9 - SUMMARY OF ESTIMATED DIRECT ENERGY INTENSIVENESS FOR DOMESTIC TRANSPORT, 1975-76

Transport Mode	Passenger (MJ/passenger-km)			Freight (MJ/tonne-km)		
	Urban	Non-urban	Mean	Urban	Non-urban	Mean
Road						
Cars & Station Wagons	3.2	1.2	2.2	-	-	-
Motorcycles	2.2	1.5	1.9	-	-	-
Utilities & Panel Vans	na	na	2.7	na	na	22.7
Trucks	-	-	-	4.1	2.0	2.7
Buses	1.3	0.6	0.9	-	-	-
Rail						
Trams	1.9	-	1.9	-	-	-
Government Trains	1.9	0.8	1.6	-	0.6	0.6
Non-Government Trains	-	-	-	-	0.1	0.1
Air						
Domestic Airlines	-	4.1	4.1	-	45.4	45.4
General Aviation	-	7.0	7.0	-	77.8	77.8
Sea, Coastal	-	-	-	-	0.3	0.3

Note: This table has been developed as the basis for time series comparison within each mode. The use of the above data for making comparisons between modes is dangerous.

Source: Tables 3.16, 3.17, 4.12, 4.13 and 5.9, and text of Chapters 4 and 6.

Direct Energy Intensiveness - International Transport

Table 8.10 shows that shipping was very much less energy intensive than aircraft for freight transport.

TABLE 8.10 - SUMMARY OF ESTIMATED DIRECT ENERGY INTENSIVENESS FOR INTERNATIONAL TRANSPORT, 1975-76

Transport Mode	Passenger (MJ/passenger-km)	Freight (MJ/tonne-km)
Air	2.3	25.5
Sea(a)	-	0.2

(a) All direct energy consumed by ships was attributed to freight transport. Thus no intensiveness figure was estimated for sea passenger travel.

Source: Table 5.9 and text of Chapter 6.

COMPARISON OF TRANSPORT TASK AND ENERGY CONSUMPTION, 1970-71 AND 1975-76

While it is highly desirable to compare the transport task, direct and indirect energy consumption and energy intensiveness data for 1970-71 and 1975-76, it was not possible to do this comprehensively because of the lack of certain data, differences in the ways data were analysed and the different assumptions made in Occasional Paper 4 and in this report.

However, it was possible to compare a limited amount of data from some of these categories, as shown in Table 8.11. The Table implies that there had been an increase in the total distance travelled and a relatively greater increase in energy consumption by most modes over the 5 year period. There was a slight increase in the energy intensiveness of cars and station wagons over the period.

TABLE 8.11 - COMPARISON OF TOTAL DISTANCE TRAVELLED, PASSENGER AND FREIGHT TASK, ENERGY CONSUMPTION AND ENERGY INTENSIVENESS FOR DOMESTIC ROAD, RAIL AND AIR MODES, 1970-71 AND 1975-76

(Growth 1970-71 to 1975-76 as percentage of 1970-71 figure)

Transport Mode	Distance	Pass-km	Tonne-km	Energy Consumption	Energy Intensiveness
Road					
Cars & Station Wagons	+23	+24	-	+26	+2 (a)
Motorcycles	+62	+60	-	+123	+39 (a)
Utilities & Panel Vans	+43	na	+63	+90	na
Trucks	+10	na	+36	+22	na
Buses	-10	na	na	+1	na
Trams	-6	na	na	na	na
Rail					
Government					
Passenger	-5	na	-	na	na
Freight	-3	-	+22	na	na
Non-Government	na	na	+91	na	na
Air, Domestic	+13	+45	+7	na	na

(a) Refers to mean passenger task.

Source: Tables 3.1, 3.4, 3.9, 3.10, 3.16, 4.5, 5.1 and 5.8.
ABS, *Rail, Bus and Air Transport, 1975-76*, Canberra 1977, Ref. 14.21.
Clark N. and Associates, *Transport and Energy in Australia Part 2 - Consumption by Categories*, Occasional Paper 4, Bureau of Transport Economics, Canberra 1975. Department of Civil Aviation, *Australian Air Transport Statistics, Year ended 30 June 1971*, Melbourne 1971.

TOTAL CONSUMPTION

Total direct national non-military transport energy consumption was estimated at 699 PJ for 1975-76 and was almost entirely oil-based. The magnitude of indirect national transport energy consumption was 160 PJ (127 PJ being oil-based) for the same period. Thus national transport energy consumption was estimated as 859 PJ in 1975-76. Of this amount, 826 PJ (96 per cent) was estimated to be oil based.

NEED FOR FURTHER INFORMATION AND INVESTIGATIONS

A lack of standardisation of definitions is apparent in considering indirect energy, where it is necessary to decide at what point the energy inputs to various 'indirect' activities can be assumed to make negligible contribution.

In published energy statistics, it is important that the accounting boundaries be clearly stated, so that it is evident, for example, how imported or exported fuels are accounted for. Appropriate averaging factors should also be clearly stated to permit ready conversion from units of mass or volume to energy units.

It would be of great assistance if data published on electricity consumption in Australia were disaggregated in accordance with the categories of the Australian Standard Industrial Classification (ASIC). This would permit ready comparison with data on the usage of other fuels.

It would also be useful if better estimates were developed of the efficiency of input energy by the various sectors of the Australian economy.

The analysis presented in this paper has been based in part on a number of assumptions, the accuracy of which cannot be precisely estimated. While it is felt that the estimates of transport task and energy consumption for most modes/vehicle classes are reasonably well founded, it is clear that the analysis carried out could be much improved if some additional data were available.

With regard to the road mode, occupancy data are needed for all vehicle types on a two-way basis broken down into urban/non-urban operation and by trip purpose.

It would be desirable in future for data on fuel type to be collected for cars and station wagons.

Fuel consumption data are needed for each vehicle category operating in urban and non-urban areas. Alternatively, the ratio of fuel consumed in urban and non-urban areas could be obtained for analysis purposes.

It is highly desirable that the transport task (passenger and freight) be disaggregated by area of operation and that bus data be collected with the same degree of detail as for other road vehicles.

For the rail mode, one immediate need is for estimates of passenger-km performed by trams in Melbourne and Adelaide.

Details of the quantity of electricity used by Melbourne trams would be useful.

The following train information would permit improved analysis:

- urban passenger journeys for Western Australia;
- urban passenger-km for New South Wales, Queensland and Western Australia; and
- non-urban passenger-km for New South Wales and Queensland.

A breakdown of rail energy data on a three-way classification basis, i.e. passenger/freight, urban/non-urban, and electric/non-electric, would be of considerable value. If this energy data cannot be collected, it would be desirable to collect data on trailing tonnes per train-km for non-urban passenger and freight in all states other than New South Wales as a basis for energy estimation.

With regard to the air mode, it is desirable that information be collected on fuel uplifted in Australia by international airlines and on the international air transport task with respect to passenger-km, passenger tonne-km, and freight tonne-km.

Domestic air transport fuel consumption data should be collected and should differentiate between scheduled, general aviation and other services.

For the sea mode, data are needed on the overseas freight task and the energy consumed by the trading fleet broken down into the coastal trading fleet and the international trading fleet (for energy uplifted in Australia only).

APPENDIX I

ADDITIONAL NOTES ON ROAD TRANSPORT (CHAPTER 3)

In Chapter 3, the category headings for the tables are presented without explanation. In most cases these correspond directly with corresponding headings used by the Australian Bureau of Statistics.

Definitions and explanations of headings where appropriate, are provided below.

Area of Operation

Capital City:	Includes the six State capital cities, Darwin, and the A.C.T. (for A.C.T. vehicles only).
Provincial Urban:	Centres, other than those in 'Capital City', which had a population exceeding 40 000 at the time of the 1971 census. This covers Newcastle, Wollongong, Port Kembla, Geelong, Ballarat, Bendigo, Gold Coast, Toowoomba, Rockhampton, Townsville and Launceston. It also includes travel on the Stuart and Barkly highways (for Northern Territory vehicles only).
Rest of State:	Intrastate travel not covered by the categories of 'Capital City' or 'Provincial Urban'.
Interstate:	This covers travel only in other States by vehicles registered in the home State. Thus it would not, for example, include the NSW leg of interstate journeys by vehicles registered in NSW.

Purpose

Business:	Includes distance travelled for hire and reward, or charged to a business expense or for which allowance was received (except for work travel).
To and from Work:	Includes only travel between place of residence and place of work at the beginning and end of each work day.

Trucks

Other Truck Type Vehicles	Includes vehicles such as ambulances, hearses, fire engines, which are included with trucks in tables of distance travelled, but which do not perform a freight task.

APPENDIX II

ADDITIONAL NOTES ON RAIL TRANSPORT (CHAPTER 4)

PASSENGER TASK ESTIMATES

For the railway passenger task, outlined in Table 4.2, certain entries were not available from the published literature. These were:

- urban passenger journeys for Western Australia;
- urban passenger-km for New South Wales, Queensland and Western Australia; and
- non-urban passenger-km for New South Wales and Queensland.

Urban Passenger Journeys

For Western Australia, the level of urban passenger journeys was estimated using a linear regression model, relating urban passenger journeys and passenger train-km. Data values used were for all other States except Tasmania. The estimated value was 11.379 x 10^6 passenger journeys.

Urban Passenger-km

Values were estimated by firstly computing the ratio

$$\frac{\text{passenger-km}}{\text{train-km} \times \text{passenger journeys}}$$

for Victoria and South Australia. On the basis of similar capital city sizes, the ratio for Victoria was assumed to be applicable to New South Wales. Similarly, the ratio for South Australia was applied to Queensland and Western Australia. Using these ratios with known values of train-km and passenger journeys values, the following passenger-km were derived:

New South Wales:	3.403×10^9
Queensland:	0.419×10^9
Western Australia:	0.099×10^9

Non-urban passenger-km

Values for New South Wales and Queensland were estimated using a linear regression model relating non-urban passenger-km to train-km and passenger journeys. Table entries for the other four States constituted the data values. The estimates derived were:

New South Wales:	0.869×10^9
Queensland:	0.350×10^9

GOVERNMENT RAILWAYS' USE OF FUELS

The consumption of various types of fuel by Government railway systems in Australia is set out in Table II.1.

DIRECT ENERGY CONSUMPTION BY ELECTRIC RAIL

The direct energy consumption of trams and electric heavy rail was defined to include losses in generation and supply of electricity, for the three States using electric traction, and are shown in Table II.2. Calculations were based upon the following data, published by ESAA[1].

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(1) Electricity Supply Association of Australia, *op.cit.*, Table 6.

TABLE II.1 - CONSUMPTION OF COAL, DIESEL OIL AND PETROL BY GOVERNMENT RAILWAYS, 1975-76

Quantity of Fuel Consumed (Energy equivalent)[a]	NSW	VIC	QLD	SA	WA	TAS	Sub Total - States	National	TOTAL
Coal used in locomotives tonnes	-	1 810 (0.045)	90 (0.002)	173 (0.004)	22 (0.001)	197 (0.005)	2 292 (0.057)	-	2 292 (0.057)
Oil in diesel locomotives and rail cars ML	184.40[a] (7.118)	74.50 (2.876)	152.85 (5.900)	45.98 (1.775)	53.09 (2.049)	8.01 (0.309)	518.83[a] (20.027)	40.38 (1.559)	559.20[a] (21.585)
Oil in furnaces of steam locomotives ML	-	-	-	0.009 neg	-	-	0.009 neg	-	0.009 neg
Petrol in rail cars ML	-	-	-	-	0.05 neg	-	0.05 neg	-	0.05 neg
TOTAL	(7.118)	(2.921)	(5.902)	(1.779)	(2.050)	(0.314)	(20.084)[b]	(1.559)	(21.643)[b]

Note: Figures in brackets are units of PJ.

(a) Energy conversion factors used were as follows: coal: 25.0 GJ/tonne; diesel: 38.3 MJ/L; petrol: 33.7 MJ/l

(b) Indicates Bureau of Transport Economics estimate.

Source: ABS, *Rail Bus and Air Transport, 1975-76*, Canberra 1977, Ref 14.21 Table 21.
Energy conversion rates were taken from Department of National Development, *End Use Analysis of Primary Fuels Demand, Australia, 1973-74 to 1986-87*, Canberra 1978.

TABLE II.2 - ELECTRICITY SALES IN THREE STATES, 1975-76

(PJ)

Purpose	NSW	VIC	SA	TOTAL
Sold for traction	1.512	1.001	0.006	2.519
Sold for all purposes	79.195	53.114	16.986	149.295

Source: Electricity Supply Association of Australia, *The Electricity Supply Industry in Australia, 1975-76*, Melbourne, April 1977. Table 6.

The overall efficiency of electricity supply was calculated for each State grid as follows:

$$\text{Efficiency} = \frac{\text{Total Electricity Sold for all Purposes}}{\text{Total Energy Value of Primary Fuel Consumed}}$$

The direct energy consumption of electric traction was thus calculated for wach State by dividing the energy value of electricity for traction (Table II.2) by the efficiency of supply (Table II.4), giving the values shown in Table II.5 below.

TABLE II.3 - CONSUMPTION OF PRIMARY FUELS IN POWER STATIONS, THREE STATES, 1975-76

Quantity of Fuel	NSW	VIC	SA	TOTAL
Black Coal tonnes x 10^6	9.049 (252.56)	-	-	(252.56)
Brown Coal tonnes x 10^6	- -	25.327 (247.19)	1.869 (26.00)	(273.19)
Brown Coal briquettes tonnes x 10^6	- -	0.162 (3.62)	- -	(3.62)
Oil tonnes x 10^6	0.053 (2.32)	0.025 (1.10)	0.09 (3.94)	(7.36)
Wood tonnes x 10^6	-	-	0.125 (2.03)	(2.03)
Natural Gas $10^6 m^3$	-		936.0 (36.62)	(36.62)
TOTAL	(254.88)	(251.91)	(68.59)	(575.38)

Note: Figures in brackets are units of PJ.

Source: Electricity Supply Association of Australia, *The Electricity Supply Industry in Australia, 1975-76*, Melbourne, April 1977. Table 3.
Energy conversion factors used were as published by the Department of National Development, *End Use Analysis of Primary Fuels Demand, Australia, 1973-74 to 1986-87*, Canberra 1978.

TABLE II.4 - OVERALL EFFICIENCY OF ELECTRICITY SUPPLY FOR THREE STATES, 1975-76

(per cent)

NSW	VIC	SA	MEAN
31.07	21.08	24.76	25.94

Note: The contribution made by hydro power towards electricity generation in NSW accounted for the apparently higher level of generation efficiency achieved by that State.

Source: Bureau of Transport Economics estimate.

TABLE II.5 - ESTIMATED DIRECT ENERGY CONSUMPTION OF ELECTRIC RAIL, INCLUDING TRAMS, 1975-76

(PJ)

NSW	VIC	SA	TOTAL
4.866	4.749	0.025	9.640

Source: Burea of Transport Economics estimate.

The figure for NSW was attributed entirely to heavy rail and that for South Australia entirely to tram operations. The figure for Victoria had to be split between trams and heavy rail. From information supplied by the Melbourne Metropolitan Tramways Board, electricity use by Melbourne trams in the year 1975-76 was taken as 0.201 PJ. Allowing for electricity supply losses, the equivalent direct energy consumption was 0.954 PJ. Subtracting 0.954 PJ from 4.749 PJ left 3.795 PJ which was taken as the direct energy consumption of victorian heavy rail.

In both Sydney and Melbourne, electric traction was employed for locomotives as well as for passenger coaching stock. It was considered reasonable to assume that coaching stock was used for passenger transport and that electric locomotives were dedicated to freight transport. The most realistic way in which to apportion the energy consumed by passenger and freight trains is in proportion to the trailing tonne-km performed by each category. Since there is no published information available on the trailing tonne-km performed by urban passenger trains, use must be made of train-km data. In the case of electric trains, total urban passenger train-km would greatly exceed total freight train-km performed in urban areas. It is considered that the error involved in assuming that energy could be apportioned according to the train-km travelled would not be great in this particular case, and has been ignored. Using the distance travelled by each category listed in Table II.6 as a proxy measure, the division of direct energy consumption between train types was estimated. Thus for NSW, 15 per cent of traction electricity was attributed to locomotives and 85 per cent to coaching stock. For Victoria the corresponding proportions were 10 per cent and 90 per cent. The results of this analysis are expressed in Table II.7.

DIRECT ENERGY CONSUMPTION - URBAN RAIL

Based on the assumptions stated in the previous paragraph, the energy totals shown in Table II.7 for rail transport were assumed to apply to freight transport <u>through</u> urban areas and passenger transport <u>in</u> urban areas.

Energy consumption by non-electric urban passenger rail was estimated by assuming that the direct energy consumption of electric and non-electric urban passenger trains respectively could be apportioned according to the distance travelled by each. These latter distances are listed in Table II.8.

From Table II.7, the direct energy consumption of urban passenger electric rail was 7.59 PJ in 1975-76, so using the overall proportions of Table II.8, that due to urban non-electric passenger rail was calculated as 3.25 PJ giving a total of 10.84 PJ for all urban passenger rail. Total urban direct energy consumption of 11.91 PJ was obtained by adding 1.07 PJ which represents the amount of energy used to transport freight through urban areas (from Table II.7 and the above discussion). The total use of diesel oil, petrol and coal for train propulsion by all Government systems amounted to 21.64 PJ (Table II.1). Adding to this the total direct energy consumption of electric rail (8.66 PJ) gave a grand total of 30.30 PJ consumed by Government railways. Finally, the total due to non-urban rail was calculated as 18.39 PJ, by subtracting the urban component from the total. In the body of the report, these results are summarised in Table 4.7.

TABLE II.6 - DISTANCE TRAVELLED BY ELECTRIC HEAVY RAIL, 1975-76

(train-km x 10^6)

State	Coaching Stock (Passenger)	Locomotives (Freight)	Total
NSW	16.453	2.860	19.313
(per cent)	(85)	(15)	(100)
Vic	14.321	1.413	15.734
(per cent)	(90)	(10)	(100)
TOTAL	30.774	4.273	35.047
(per cent)	(88)	(12)	(100)

Source: ABS; *Rail, Bus and Air Transport, 1975-76,* Canberra 1977, Table 7.

TABLE II.7 - SUMMARY OF DIRECT ENERGY CONSUMPTION BY ELECTRIC TRACTION, 1975-76

(PJ)

System	Passenger		Freight	Sub Total - Heavy Rail	TOTAL
	Trams	Coaching	Locomotives		
NSW	-	4.136	0.730	4.866	4.866
VIC	0.954	3.454	0.341	3.795	4.749
SA	0.025	-	-	-	0.025
TOTAL	0.979	7.590	1.071	8.661	9.640
(per cent)	(10)	(79)	(11)	(90)	(100)

Source: Bureau of Transport Economics estimates.

TABLE II.8 - DISTANCE TRAVELLED BY URBAN PASSENGER RAIL, 1975-76

(passenger train-km x 10^6)

System	Electric	Non-Electric	TOTAL
NSW	16.453	3.447	19.900
Vic	14.321	0.400	14.721
Qld	-	3.326	3.326
SA	-	3.640	3.640
WA	-	2.249	2.249
Tas	-	0.001	0.001
National	-	-	-
AUSTRALIA (per cent)	30.774 (70)	13.063 (30)	43.837 (100)

Source: ABS; *Rail, Bus and Air Transport, 1975-76*, Canberra 1977 Table 7.

DIRECT ENERGY CONSUMPTION: NON-URBAN PASSENGER AND FREIGHT

The use of fuel by non-urban passenger and freight trains was not known and so it was necessary to allocate the non-urban energy consumption between the two, using a suitable proxy measure. In Occasional Paper 4[(1)] this was apportioned in the ratio of the respective train-km performed by each. This approach assumed that the performance of an average freight train-km required essentially the same energy as that of an average passenger train-km.

(1) Clark N. and Associates, Occasional Paper, *op.cit.*, p.52.

The rate of energy consumption of a train is dependent upon train mass and speed. A previous BTE study[1] indicated that the rate of fuel consumption can be considered to be a linear function of train mass for a given speed and axle loading. Perry and Volframs[2] also took energy consumption to be directly proportional to train mass. When making a comparison over all passenger and freight operations it is difficult to account in any general way for differences in operating speeds and axle loadings. It is likely however, that non-urban passenger trains would average higher speeds while freight trains would experience greater axle loadings.

It was assumed that measures such as average gross tonne-km or trailing tonne-km for trains would be better proxy measures than simple train-km to apportion consumption since they take into account train mass as well as distance of travel. In the absence of published information on these parameters for the whole rail system, estimates of trailing tonne-km were developed and used to apportion energy by transport task.

For non-urban passenger trains in New South Wales, trailing tonnes per train averaged 265.1 in 1975-76[3]. The corresponding ratio for freight trains was 769.1. No data were available for other States but it was considered reasonable to apply the same value (i.e. 265.1) to passenger trains for all systems. There was much wider variation in freight train masses between State rail systems and so the figure of 769.1 for New South Wales was adjusted for other systems by the ratio:

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(1) Bureau of Transport Economics, *Mainline Upgrading: Evaluation of a Range of Options for the Melbourne-Sydney Rail Link,* November 1975, Annex C.

(2) Perry N.R.F. and Volframs A., *The Energy Cost of Road and Rail Transport in Tasmania,* University of Tasmania, 1977, p.24.

(3) Information supplied by the Public Transport Commission of New South Wales.

Average freight train load[1]
NSW average freight train load.

The ratios listed in Table II.9 were applied to values of train-km given in Tables 4.2 and 4.3 to derive estimates of trailing tonne-km performed, presented in Table II.10.

TABLE II.9 - ADJUSTED RATIOS OF TRAILING TONNE-KM FOR GOVERNMENT RAILWAY SYSTEMS

(trailing tonnes/train)

System	NSW	VIC	QLD	SA	WA	TAS	National
Freight	769.1	599.4	954.2	802.2	1 071.0	335.0	1 419.2
Passenger (non-urban)	265.1	265.1	265.1	265.1	265.1	265.1	265.1

Source: Bureau of Transport Economics estimate.

Table II.10 was used to divide the non-urban energy total from Table 4.7 (18.39 PJ), in the proportions of freight (90 per cent), and passenger (10 per cent). This yielded the values, freight (16.55 PJ) and passenger (1.84 PJ). Finally the direct energy consumption attributed to electric freight trains operating through urban areas listed as 1.07 PJ in Table 4.7, was added to the freight component. The estimates are summarised in Table 4.8 in the report.

(1) Obtained from ABS, *Rail, Bus and Air Transport, 1975-76,* Canberra 1977, Table 12.

TABLE II.10 - ESTIMATED TRAILING TONNE-KM FOR GOVERNMENT NON-URBAN RAILWAYS, 1975-76

(tonne-km x 10^9)

System	NSW	VIC	QLD	SA	WA	TAS	National	TOTAL (per cent)
Freight	18.874	6.755	22.252	3.722	10.014	0.509	5.748	67.874 (90)
Passenger (non-urban)	2.786	2.073	1.105	0.538	0.334	0.061	0.408	7.305 (10)
TOTAL	21.660	8.828	23.357	4.260	10.348	0.570	6.156	75.179 (100)

Source: Bureau of Transport Economics estimate.

DIRECT ENERGY CONSUMPTION - NON-GOVERNMENT RAILWAYS

Iron Ore Railways

The iron ore railways include those operated by Broken Hill Proprietary Co. Ltd., Hamersley Iron Proprietary Ltd., Cliffs Robe River Iron Associates, and Goldsworthy Mining Ltd. The largest of these are at Mt Newman (BHP Co. Ltd.) and Mt Tom Price (Hamersley Iron Pty. Ltd.) both in Western Australia. Together these two operations accounted for 50 per cent of tonnes carried and 85 per cent of tonne-km performed for all non-Government railways in 1975-76. They consumed 75.44 ML of automotive distillate, equivalent to 2.898 PJ, in 1975-76[(1)]. Dividing this total by their combined freight task[(1)] gave an energy intensiveness averaged between the two systems of 0.13 MJ per tonne-km.

The direct energy consumption for the remaining iron ore railways was estimated by assuming that the same energy efficiency was achieved. This estimate may be over-optimistic since the scales of other iron-ore operations do not match those of Mt Newman and Mt Tom Price, but their contribution to the total rail energy consumption was small, with a corresponding small likely error. This gave a direct energy total for iron ore railways of 3.32 PJ.

Sugar Tramways

In 1975-76, 29 sugar mills owned by a number of companies and cooperatives operated sugar tramways in Queensland, employing a total of 191 diesel and 10 steam locomotives. Since full details of sugar train operation were not obtained a representative fuel consumption efficiency was assumed to be

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(1) Information supplied by Broken Hill Co. Pty. Ltd. and Hamersley Iron Pty. Ltd.

0.017 litres per tonne-km, equivalent to 0.65 MJ per tonne-km[1]. Using this value to factor the total tonne-km, a value of 0.20 PJ was derived for the direct energy consumed.

Other Railways

These comprise railways operated in New South Wales by Broken Hill Pty Co. Ltd., South Maitland Railways Pty. Ltd., Coal and Allied Industries Ltd. and Blue Circle Southern Cement Ltd.; in Victoria by the State Electricity Commission and Australian Paper Manufacturers Ltd.; in Queensland by Comalco Ltd., Bowen Consolidated Mines Ltd. and Mackay Harbour Board; in South Australia by the Broken Hill Pty. Co. Ltd.; and in Tasmania by the Emu Bay Rail Co. Ltd.

These railways operate over short haulage distances, many being less than 20 km and none greater than 121 km in length. Thus although the tonnage carried by them in 1975-76 represented 15 per cent of the total for non-Government systems, their share of tonne-km performed was only 1 per cent, with a correspondingly small contribution to total direct energy consumption.

A paper by Thomas[2] estimated the following values of energy intensiveness for Western Australian Government railway operations in 1972-73:

Diesel train (bulk goods): 0.17 MJ/tonne-km
Diesel train (general goods); 0.50 MJ/tonne-km.

The non-Government railway systems operated primarily for transfer of bulk goods; their short distances of haul might be expected to reduce their energy efficiency to some extent. Taking the above figures as benchmark values, it was assumed

(1) Information supplied by CSR Ltd.
(2) Thomas M.H., *op.cit.*, p.6.33.

that their energy intensiveness would fall somewhere between the two. Arbitrarily choosing a value of 0.20 MJ/tonne-km which is close to the figure for bulk goods traffic in WA gave an estimated direct energy consumption of 0.06 PJ for these railways.

APPENDIX III

ADDITIONAL NOTES ON AIR TRANSPORT (CHAPTER 5)

AIR ROUTE DISTANCES

Table III.1 lists the set of route distances which were used in deriving estimates for the international air task for 1975-76. The passenger totals carried over each route are published by the Department of Transport[1].

HOURS FLOWN

Flying hours are recorded and published by the Department of Transport for all types of aircraft operations in Australia[2][3]. Tables III.2 and III.3 below, give a summary of all hours flown by Australian operators for the year ending 31 December 1976.

GENERAL AVIATION TASK

The major source of statistics covering general aviation activities, other than scheduled commuter services, is for hours flown by type of flying, described in the previous section. Details of the corresponding task are not collected but this has been estimated by the Department of Transport[4] for this study. For this analysis only the categories of charter, and private and business, were considered as contributing directly to the transport task.

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(1) Department of Transport, Australian International Air Transport Statistics, *op.cit.*, Table 5.
(2) Department of Transport, *Statistics of the Air Transport Industry - Hours Flown*, published annually for year ending 31 December.
(3) Department of Transport, Annual Report, Australian Transport *op.cit.*
(4) Research and Planning Branch, Air Transport Policy Division.

TABLE III.1 - REPRESENTATIVE AIR ROUTE DISTANCES BETWEEN AUSTRALIA AND SELECTED COUNTRIES

Country	Route-km
New Zealand	2 400
Bali	4 600
New Guinea	5 600
Fiji	5 900
Indonesia	6 000
Philippines	6 000
Malaysia	6 000
Nauru	7 000
Japan	7 800
India	10 000
Hong Kong	10 000
USA	12 800
Greece	14 000
Italy	14 000
Canada	14 500
UK	16 000
Netherlands	16 000
Germany	16 000

TABLE III.2 - SUMMARY OF HOURS FLOWN BY AUSTRALIAN AIRLINES, 1976[a]

('000)

	Domestic Airlines	Qantas[b]	TOTAL
Scheduled	262.5	81.0	343.5
Non scheduled	11.5	4.5	16.0
TOTAL	274.0	85.5	395.5

(a) Year ended 31 December.
(b) This table refers only to flights within Australia or Australian territories.

Source: Department of Transport, Annual Report, *Australian Transport, 1976-77,* Canberra 1977. Appendix 16.

TABLE III.3 - HOURS FLOWN BY TYPE OF FLYING, AUSTRALIA, 1976[a]

('000)

Type of Flying	Non-Scheduled[b] Airlines	General Aviation	TOTAL
Commuter	-	68.1	68.1
Charter	8.9	261.9	270.8
Private & Business	neg	415.5	415.5
Flying Training	5.8	267.7	273.5
Test & Ferry	1.2	26.3	27.5
Aerial Agriculture	-	65.1	65.1
Other Aerial Work	0.1	155.5	155.6
TOTAL	16.0	1 260.1	1 276.1

(a) Year ended 31 December.
(b) Includes domestic airlines, and Qantas flights within Australia or Australian territories.

Source: Department of Transport, Annual Report, *Australian Transport, 1976-77,* Canberra 1977. Appendix 16.

The performance estimates were calculated by multiplying hours flown by a representative aircraft speed to derive aircraft-km flown. This figure was then multiplied by assumed passenger and freight load factors to derive passenger-km and freight tonne-km respectively. Finally the passenger tonne-km was inferred from the passenger-km estimates by assuming an average passenger weight of 90 kg.

APPENDIX IV

ADDITIONAL NOTES ON SEA TRANSPORT (CHAPTER 6)

TRANSPORT TASK PERFORMED BY FERRIES

While ferries contribute only a small proportion of the overall passenger task, they were an important feature of the transport system in some cities. The level of ferry patronage in 1975-76 is shown in Table IV.1 below. The corresponding passenger-km were not known, but can be assumed negligible by comparison with urban road and rail tasks, as can the direct energy consumption.

TABLE IV.1 - PASSENGERS CARRIED BY FERRY SERVICES, 1975-76

State	Passenger Journeys x 10^3
New South Wales	
Sydney	10 271
Newcastle	1 184
Queensland	
Brisbane	2 000
Western Australia	
Perth	426
Tasmania	
Hobart	6 869 (a)
TOTAL	20 750

Note: Passenger ferry services in Victoria were not extensive. There were no services operating in South Australia.

(a) The level of passengers increased sharply between 1973-74 and 1974-75 due to the collapse of the Tasman Bridge on 5 January 1975.

Source: ABS, *Rail, Bus and Air Transport, 1975-76*, Canberra 1977, Table 35.
Bureau of Transport Economics, Information Paper, *Urban Public Transport Statistics*, June 1977.

PASSENGER TASK BY COASTAL SHIPPING

Cruise Passenger

Table IV.2 indicates the available information describing the operations of cruise ships. These are defined by the ABS as voyages which begin and end in Australia, do not exceed six weeks in duration, and are confined to ports adjoining the western Pacific and eastern Indian Oceans. In order to estimate the passenger task by cruise vessels, an average speed while cruising was assumed to be 20 knots, with two-thirds of the duration of a cruise spent actually travelling. Thus a representative distance travelled per day was 20 x 24 x 2/3 = 320 nautical miles, or 600 km. This figure was used to factor the entries in Table IV.2.

Interstate Passenger

A full origin and destination matrix of interstate passenger movements by sea is published by ABS(1) and is not repeated here. These data were multiplied by coastal sailing distances, listed in Table IV.3, to derive an estimate for the passenger-km travelled.

OVERSEAS FREIGHT

Table IV.4 lists the representative sea distances which were used to multiply the tonnage figures in Table 6.3 to obtain the corresponding tonne-km estimates presented in Table 6.4.

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(1) ABS, Passenger Movements by Sea at Australian Ports, 1975, *op.cit.*, Table 7.

TABLE IV.2 - PERFORMANCE OF CRUISE SHIPS, 1975[a]

	Cruise Analysis								TOTAL
No. of cruises of each duration	1	2	12	39	17	7	5	7	90
Average cruise duration (days)	3	8	11	14	17	20	26	31	
Total No. of passengers returning	659	711	44 934	611	213	4 798	894	3 034	70 599

(a) Year ended 31st December. Corresponding data for 1976 were not available.

Source: ABS, *Passenger Movement by Sea at Australian Ports*, Canberra 1975, Ref 3405.0 Table 5.

TABLE IV.3 - AUSTRALIAN COASTAL SAILING DISTANCES

From	To	Distance (km)
Sydney	Melbourne	1 010
	Brisbane	860
	Cairns	2 280
	Townsville	2 010
	Adelaide	1 800
	Fremantle	3 970
	Hobart	1 160
	Launceston	920
	Burnie	965
Melbourne	Brisbane	1 850
	Fremantle	3 020
	Adelaide	840
	Devonport	350
Brisbane	Fremantle	4 810
	Hobart	2 000
Adelaide	Fremantle	2 485
Fremantle	Hobart	3 340

Source: Department of Transport, Canberra.

TABLE IV.4 - REPRESENTATIVE DISTANCES FOR CALCULATING THE OVERSEAS FREIGHT TASK

Area	Representative Ports	Distance (km)
N. American and Hawaiian Islands	Melbourne-Norfolk (Va)	18 070
South America	Melbourne-Valparaiso	11 670
Europe (incl USSR)	Melbourne-London	20 400
Africa	Melbourne-Dar es Salaam	11 070
Eastern Asia	Melbourne-Tokyo	9 150
Other Asia	Melbourne-Abadan	12 950
Papua NG, New Zealand and Pacific Islands	Adelaide-Auckland	3 770
Indian Ocean Islands and Antarctic Area	Adelaide-Auckland	3 770

Source: Carey R.W., *Reed's marine distance tables*, compiled for the publisher by Carey R.W. and Reynolds J.E., Third Edition, London, T. Reed, 1976.

OVERSEAS PASSENGER

Table IV.5 indicates the representative distances which were used to multiply the passenger totals to derive estimates for passenger-km travelled on international shipping to and from Australia (see Chapter 6, Table 6.6).

TABLE IV.5 - REPRESENTATIVE DISTANCES FOR CALCULATING THE OVERSEAS PASSENGER TASK

Area	Representative Ports	Distance (km)
Africa	Melbourne-Capetown	11 280
America	Melbourne-Norfolk (Va)	18 670
Asia	Melbourne-Singapore	7 140
Europe-Mediterrean (Italy, Malta, Greece Yugoslavia)	Melbourne-Tunis	16 710
Europe-Other	Melbourne-London	20 410
Oceania	Sydney-Auckland	2 360
Not Stated	Average of all other distances	12 660

Source: Carey R.W., *Reed's marine distance tables*, compiled for the publisher by Carey R.W. and Reynolds J.E., Third Edition, London, T. Reed, 1976.

DIRECT ENERGY CONSUMPTION BY COASTAL SHIPPING

The operating data in Table IV.6 below represent estimated average values for the Australian coastal trading fleet. If these are taken as representative, then the total fuel oil consumed by them in 1975-76 can be calculated. Table IV.7 shows the proportions of consumption due to interstate and intrastate vessels, calculated on this basis, to be about 90 and 10 per cent respectively.

TABLE IV.6 - VESSELS OF THE AUSTRALIAN COASTAL TRADING FLEET OPERATING 1975-76

	No. of vessels	Average DWT (tonnes)	Typical Speed (knots)	Typical use[a] of fuel oil while at sea (tonnes/day)	Typical[a] Annual Utilisation Factor (per cent)
Interstate	72	24 350	16	36	45
Intrastate	22	14 600	12	12	45

(a) Bureau of Transport Economics estimates.

Sources: Department of Transport, *Australian Shipping and Shipbuilding, at 30 June 1976*, 29th edition, AGPS Canberra, 1977.
Australian National Line, *Ships Statistics*, revision 4/78, 1978.

TABLE IV.7 - ESTIMATED CONSUMPTION OF FUEL OIL BY COASTAL SHIPPING, 1975-76

Category of Task	Calculation		Annual consumption (tonnes x 10^3)	(per cent)
Interstate	72 x 36 x 365 x 45%	=	425.74	(91)
Intrastate	22 x 12 x 365 x 45%	=	43.36	(9)
TOTAL			469.10	(100)

Source: Bureau of Transport Economics estimates and Table IV.6.

Referring back to Table 6.8, the total amount of fuel oil uplifted for non-military purposes in 1975-76 was 1610 x 10^3 tonnes. The quantity of 469 x 10^3 tonnes from Table IV.7 represented 29 per cent of the total usage of fuel oil bunkers. Thus 71 per cent of fuel oil bunkers was uplifted by overseas vessels. The same proportion of coastal (29 per cent) and overseas (71 per cent) uplifted was assumed for automotive distillate and industrial diesel fuel bunkers, allowing an overall allocation of bunkers between coastal and overseas shipping to be made.

Expressed in energy terms, the energy value of all non-military bunkers uplifted in Australia (86.65 PJ) was divided as follows: coastal shipping (25.13 PJ), overseas shipping (61.52 PJ).

APPENDIX V

FURTHER TABLES FROM THE ABS SURVEYS OF MOTOR VEHICLE USAGE AND BUS FLEET OPERATIONS

This supplement contains tabulations of the task and fuel consumption of road vehicles, removed from Chapter 3 to retain clarity in the body of the report. Tables V.1-V.22 were obtained from the ABS Survey of Motor Vehicle Usage, year ended 30 September 1976, while Table V.23 was obtained from the ABS Survey of Bus Fleet Operations, year ended 30 June 1976. Explanations of terms used in the tabulated headings are given in Appendix I.

The tables are subdivided as follows:

Subject	Table Nos.
Distance Travelled	V.1-V.8
Occupant Task	V.9-V.10
Load Carried	V.11-V.12
Freight Task	V.13-V.17
Fuel Consumption	V.18-V.22
Bus Passengers	V.23

TABLE V.1 - TOTAL DISTANCE TRAVELLED BY CARS AND STATION WAGONS BY STATE OF REGISTRATION AND AREA OF OPERATION, 1976[a]

(km x 10^6)

State of Registration	Area of Operation: Capital City	Provincial Urban	SUBTOTAL - Urban	Rest of State	Inter-State	TOTAL All Areas	(per cent)
NSW	14 646	3 297	17 943	7 638	1 174	26 755	(34)
VIC	12 775	2 112	14 887	6 653	1 250	22 790	(29)
QLD	4 281	2 114	6 395	3 641	480	10 516	(13)
SA	5 028	-	5 028	2 251	336	7 615	(10)
WA	4 512	-	4 512	2 382	118	7 012	(9)
TAS	726	340	1 066	1 047	55	2 168	(3)
NT	154	58	212	57	26	295	(1)
ACT	1 088	-	1 088	-	373	1 381	(2)
AUSTRALIA	43 130	7 921	51 051	23 669	3 811	78 531	(100)
(per cent)	(55)	(10)	(65)	(30)	(5)	(100)	

(a) Year ended 30 September.

Source: ABS, *Survey of Motor Vehicle Usage*, year ended 30 September 1976, Canberra 1978, Ref 9202.0. Table 2A.

TABLE V.2 - TOTAL DISTANCE TRAVELLED BY CARS AND STATION WAGONS, BY STATE OF REGISTRATION AND PURPOSE, 1976[a]

(km x 10^6)

State of Registration	Purpose				TOTAL All Purposes
	Business	Paid to and from work	Unpaid to and from work	Private travel	
NSW	5 353	872	5 629	14 901	26 755
VIC	4 568	766	4 584	12 872	22 790
QLD	2 089	314	2 009	6 104	10 516
SA	1 437	199	1 546	4 433	7 615
WA	1 468	124	1 590	3 830	7 012
TAS	385	75	436	1 272	2 168
NT	82	11	50	152	295
ACT	202	74	352	753	1 381
AUSTRALIA (per cent)	15 584 (20)	2 435 (3)	16 197 (21)	44 315 (56)	78 531 (100)

(a) Year ended 30 September.

Source: ABS, *Survey of Motor Vehicle Usage*, year ended 30 September 1976, Canberra 1978, Ref 9202.0, Table 7A.

TABLE V.3 - TOTAL DISTANCE TRAVELLED BY ROAD VEHICLES (EXCLUDING BUSES) BY YEAR OF MANUFACTURE, 1976[(a)]

(km x 10^6)

Vehicle Type	Year of Manufacture								TOTAL
	Before 1955	1955-1959	1960-1964	1965-1969	1970-1974	1975	1976	Unknown	All Years
Cars and Station Wagons (Tare weight - kg)									
under 1100	124	690	2 114	4 999	14 525	3 665	1 001	39	27 156
1100 and under 1300	19	108	3 893	8 401	9111	2 089	583	14	24 219
1300 and over	47	95	387	4 200	16 699	4 183	1 418	27	27 156
SUBTOTAL									
Cars and Station Wagons	189	893	6 494	17 600	40 335	9 937	3 002	80	78 531
(per cent)	(1)	(1)	(8)	(22)	(51)	(13)	(4)	(1)	(100)
Motorcycles	12	3	35	55	1 056	378	76	25	1 641
Utilities and Panel Vans	86	148	839	2 716	6 004	1 800	669	28	12 290
Trucks									
petrol	61	113	366	1 167	2 460	688	289	8	5 072
other	6	8	94	574	1 769	599	325	10	3 385
TOTAL	354	1 166	7 826	22 113	51 624	13 322	4 362	151	100 919

(a) Year ended 30 September.

Source: ABS, *Survey of Motor Vehicle Usage*, year ended 30 September 1976, Canberra 1978, Ref 9202.0, Table 9.

TABLE V.4 - AVERAGE DISTANCE TRAVELLED BY ROAD VEHICLES (EXCLUDING BUSES) BY YEAR OF MANUFACTURE, 1976[a]

(km)

Vehicle Type	Year of Manufacture								MEAN
	Before 1955	1955-1959	1960-1964	1965-1969	1970-1974	1975	1976	Unknown	All Years
Cars and Station Wagons (Tare weight - kg)									
under 1100	5 294	8 781	9 464	11 003	13 794	17 477	16 413	10 342	12 889
1100 and under 1300	3 624	7 859	14 770	14 298	16 802	19 584	19 231	4 748	15 601
1300 and over	6 653	12 463	13 070	15 086	18 978	23 645	23 967	25 551	18 762
MEAN									
Cars and Station Wagons	5 399	8 844	12 415	13 334	16 279	20 116	20 011	9 988	15 378
Motorcycles	3 476	1 736	5 707	2 360	5 416	8 043	5 807	6 496	5 586
Utilities and Panel Vans	6 693	10 809	9 904	14 540	18 864	22 285	22 854	10 707	16 860
Trucks									
petrol	2 774	4 805	7 708	12 971	19 305	21 499	22 797	4 881	14 363
other	5 390	5 763	11 348	19 879	38 356	50 100	53 564	29 296	32 508
OVERALL MEAN	4 719	8 310	11 670	13 406	16 327	20 146	20 608	9 238	15 322

(a) Year ended 30 September.

Source: ABS, *Survey of Motor Vehicle Usage*, year ended 30 September 1976, Canberra 1978, Ref 9202.0, Table 9.

TABLE V.5 - TOTAL DISTANCE TRAVELLED BY UTILITIES, PANEL VANS AND TRUCKS USED IN BUSINESS, BY INDUSTRY SERVED AND TYPE OF USAGE, 1976 (a)

(km x 10^6)

Industry Served	Type of Usage			TOTAL
	Hire and Reward	Used in Own Business	Not Stated	All Usages
Agriculture, Forestry, Fishing and Hunting	224	2 685	17	2 926
Mining	131	199	neg	329
Manufacturing	219	887	13	1 119
Building and Construction	506	1 861	2	2 369
Wholesale and Retail Trade	292	2 207	33	2 532
Road Transport	2 494	-	-	2 494
Australian, State and Local Govt.	114	1 489	1	1 604
Other	141	1 313	3	1 458
Not Stated	7	21	116	144
TOTAL	4 128	10 661	185	14 975

(a) Year ended 30 September.

Source: ABS, *Survey of Motor Vehicle Usage*, year ended 30 September 1976, Canberra 1978, Ref 9202.0, Table 10.

TABLE V.6 - TOTAL DISTANCE TRAVELLED BY TRUCKS, BY TARE WEIGHT AND AREA OF OPERATION, 1976[(a)]

(km x 10^6)

Tare Weight (tonnes)	Area of Operation					TOTAL All Areas
	Capital City	Provincial Urban	SUBTOTAL - Urban	Rest of State	Inter-State	
Rigid						
under 3	1 422	303	1 725	1 344	46	3 115
3 and under 4	510	75	585	339	16	941
4 and over	861	150	1 011	880	84	1 976
SUBTOTAL Rigid	2 792	529	3 321	2 563	147	6 032
Articulated						
under 9	124	28	152	189	37	377
9 and under 11	114	43	156	228	114	499
11 and over	197	93	290	479	360	1 128
SUBTOTAL Articulated	435	164	599	895	511	2 005
Other Truck Type Vehicles	149	58	207	164	49	420
TOTAL	3 377	750	4 127	3 623	707	8 457
(per cent)	(40)	(9)	(49)	(43)	(8)	(100)

(a) Year ended 30 September.

Source: ABS, *Survey of Motor Vehicle Usage*, year ended 30 September 1976, Canberra 1978, Ref 9202.0. Table 2B.

TABLE V.7 - TOTAL DISTANCE TRAVELLED BY TRUCKS, BY TARE WEIGHT AND PURPOSE, 1976[(a)]

(km x 10^6)

Tare Weight (tonnes)	Purpose						TOTAL
	Business - Laden	Business - Unladen	SUBTOTAL - Business	Paid to and from work	Unpaid to and from work	Private Travel	All Purposes
Rigid							
under 3	1 884	792	2 676	36	146	256	3 115
3 and under 4	636	271	909	6	17	9	941
4 and over	1 249	669	1 921	9	33	13	1 976
SUBTOTAL							
Rigid	3 769	1 732	5 506	51	195	279	6 032
Articulated							
under 9	238	130	369	2	5	2	377
9 and under 11	349	143	493	1	4	1	499
11 and over	609	304	1 113	2	12	2	1 128
SUBTOTAL							
Articulated	1 396	578	1 075	5	21	4	2 005
TOTAL	5 165	2 309	7 704	59	246	448	8 457
(per cent)	(61)	(27)	(91)	(1)	(3)	(5)	(100)

(a) Year ended 30 September.

Source: ABS, *Survey of Motor Vehicle Usage*, year ended 30 September 1976, Canberra 1978, Ref 9202.0, Table 7A.

TABLE V.8 - TOTAL DISTANCE TRAVELLED BY TRUCKS, BY STATE OF REGISTRATION AND AREA OF OPERATION, 1976[a]

(km x 10^6)

State of Registration	Area of Operation: Capital City	Provincial Urban	SUBTOTAL - Urban	Rest of State	Inter-State	TOTAL All Areas	(per cent)
NSW	1 054	300	1 353	1 078	200	2 632	(31)
VIC	966	139	1 105	656	169	1 931	(23)
QLD	531	269	800	809	68	1 677	(20)
SA	355	-	355	335	238	928	(11)
WA	346	-	346	578	13	937	(11)
TAS	53	28	81	149	3	233	(3)
NT	17	16	33	17	3	53	(1)
ACT	55	-	55	-	12	66	(1)
AUSTRALIA	3 377	750	4 127	3 623	707	8 457	(100)
(per cent)	(40)	(9)	(49)	(43)	(8)	(100)	

(a) Year ended 30 September.

Source: ABS, *urvey of Motor Vehicle Usage*, year ended 30 September 1976, Canberra 1978, Ref 9202.0, Table 2A.

TABLE V.9 - ESTIMATED OCCUPANT TASK BY ROAD VEHICLES (EXCLUDING BUSES), BY AREA OF OPERATION, 1976[a]

(occupant-km x 10^9)

Vehicle Type	Area of Operation		TOTAL All Areas	(per cent)
	Capital City	All Other		
Cars and Station Wagons	78.51 (1.82)	77.16 (2.18)	155.67 (1.98)	(83)
Motorcycles	0.83 (1.06)	0.96 (1.12)	1.78 (1.09)	(1)
Utilities and Panel Vans	7.66 (1.45)	11.53 (1.65)	19.19 (1.56)	(10)
Trucks	4.26 (1.26)	6.68 (1.32)	10.94 (1.29)	(6)
TOTAL	91.26 (1.74)	96.33 (1.99)	187.59 (1.86)	(100)

Note: Figures shown in brackets below each table entry are average vehicle occupancy rates, expressed in persons per vehicle.

(a) Year ended 30 September.

Source: ABS, *Survey of Motor Vehicle Usage*, year ended 30 September 1976, Canberra 1978, Ref 9202.0, Table 39.

TABLE V.10 - ESTIMATED OCCUPANT TASK BY CARS AND STATION WAGONS, BY STATE OF REGISTRATION AND AREA OF OPERATION, 1976[(a)]

(occupant-km x 10^9)

State of Registration	Area of Operation Capital City	All Other	TOTAL All Areas	(per cent)
NSW	25.99	25.64	51.63	(33)
VIC	23.16	22.39	45.55	(29)
QLD	8.42	13.29	21.71	(14)
SA	9.30	6.09	15.39	(10)
WA	8.11	5.50	13.61	(9)
TAS	1.43	3.09	4.51	(3)
NT	0.27	0.32	0.59	(1)
ACT	1.83	0.85	2.68	(2)
AUSTRALIA	78.51	77.16	155.67	(100)
(per cent)	(50)	(50)	(100)	

(a) Year ended 30 September.

Source: ABS, *Survey of Motor Vehicle Usage*, year ended 30 September 1976, Canberra 1978, Ref 9202.0, Table 39.

TABLE V .11 - TOTAL TONNES CARRIED BY UTILITIES, PANEL VANS AND TRUCKS, BY INDUSTRY SERVED AND TYPE OF USAGE, 1976[(a)]

(tonnes x 10^6)

Industry Served	Type of Usage			TOTAL
	Hire and Reward	Used in Own Business	Not Stated	All Usages
Agriculture, Forestry, Fishing and Hunting	20.55	77.37	0.42	98.34
Mining	46.91	28.76	0.03	75.70
Manufacturing	23.27	39.23	0.09	62.59
Building and Construction	77.61	53.88	0.71	132.21
Wholesale and Retail Trade	12.53	54.02	0.12	66.67
Road Transport	165.99	-	-	165.99
Australian, State and Local Govt.	16.77	104.47	0.15	121.38
Other	8.77	21.86	0.11	30.75
Not Stated	0.48	0.65	1.89	3.02
TOTAL	372.88	380.24	3.52	756.66

(a) Year ended 30 September.

Source: ABS, *Survey of Motor Vehicle Usage*, year ended 30 September 1976, Canberra 1978, Ref 9202.0, Table 18.

TABLE V.12 - AVERAGE LOAD CARRIED WHEN LOADED BY UTILITIES, PANEL VANS AND TRUCKS ON BUSINESS, BY TYPE OF USAGE, 1976[(a)]

(tonnes)

Vehicle Type	Type of Usage			MEAN
	Hire and Reward	Used in Own Business	Not Stated	All Usages
Utilities and Panel Vans	0.38	0.38	0.31	0.37
Trucks: (Tare Weight - tonnes) Rigid				
under 3	1.22	1.08	0.84	1.10
3 and under 4	3.32	3.60	2.78	3.54
4 and over	7.13	5.48	6.48	6.07
MEAN				
Rigid	4.75	2.58	2.28	2.99
Articulated				
under 9	11.30	9.21	10.13	10.27
9 and under 11	13.94	12.41	13.05	13.53
11 and over	17.50	16.77	11.66	17.32
MEAN				
Articulated	14.90	11.95	11.66	13.94
MEAN				
Trucks	7.60	2.98	2.81	4.07
OVERALL MEAN	5.83	1.63	0.90	2.31

(a) Year ended 30 September.

Source: ABS, *Survey of Motor Vehicle Usage*, year ended 30 September 1976, Canberra 1978, Ref 9202.0, Table 15.

TABLE V.13 - FREIGHT TASK PERFORMED BY UTILITIES, PANEL VANS AND TRUCKS, BY AREA OF OPERATION, 1976[(a)]

(tonne-km x 10^9)

Vehicle Type	Area of Operation					TOTAL
	Capital City	Provincial Urban	SUBTOTAL - Urban	Rest of State	Inter-State	All Areas
Utilities and Panel Vans	0.821	0.160	0.977	0.554	0.041	1.577
Trucks: (Tare Weight - tonnes)						
Rigid						
under 3	0.941	0.179	1.120	0.714	0.025	1.859
3 and under 4	1.008	0.141	1.149	0.779	0.043	1.970
4 and over	3.438	0.676	4.114	3.732	0.410	8.256
SUBTOTAL Rigid	5.387	0.996	6.383	5.224	0.477	12.085
Articulated						
under 9	0.866	0.221	1.087	1.468	0.381	2.936
9 and under 11	1.056	0.441	1.497	2.257	1.476	5.231
11 and over	2.170	0.984	3.154	5.931	5.789	14.874
SUBTOTAL Articulated	4.092	1.646	5.738	9.656	7.645	23.041
SUBTOTAL Trucks	9.749	2.643	12.122	14.880	8.123	35.126
TOTAL	10.300	2.803	13.103	15.434	8.164	36.702
(per cent)	(28)	(8)	(36)	(42)	(22)	(100)

(a) Year ended 30 September.

Source: ABS, *Survey of Motor Vehicle Usage*, year ended 30 September 1976, Canberra 1978, Ref 9202.0. Table 3.

TABLE V.14 - FREIGHT TASK PERFORMED BY UTILITIES, PANEL VANS AND TRUCKS, BY MAIN TYPE OF OPERATION, 1976[(a)]

Main Type of Operation	Tonnes Carried x 10^6	(per cent)	Tonne-km x 10^9	(per cent)
Within capital city of State of registration	313.93	(42)	8.453	(23)
Between capital city and rest of State	34.53	(5)	4.602	(13)
Outside capital city but within 80 km of base	302.62	(40)	6.413	(17)
Outside capital city but beyond 80 km of base	84.86	(11)	6.956	(19)
Intercapital	8.68	(1)	6.859	(19)
Other interstate within 80 km of base	2.99	(1)	0.167	(1)
Other interstate beyond 80 km of base	8.96	(1)	3.252	(9)
TOTAL	756.64	(100)	36.702	(100)

(a) Year ended 30 September.

Source: ABS, *Survey of Motor Vehicle Usage,* year ended 30 September 1976, Canberra 1978, Ref 9202.0, Tables 29, 30.

TABLE V.15 - FREIGHT TASK PERFORMED BY UTILITIES, PANEL VANS AND TRUCKS, BY INDUSTRY SERVED AND TYPE OF USAGE, 1976[(a)]

(tonnes x 10^9)

Industry Served	Type of Usage			TOTAL
	Hire and Reward	Used in Own Business	Not Stated	All Usages
Agriculture, Forestry, Fishing and Hunting	1.586	2.474	0.014	4.075
Mining	1.145	0.532	neg	1.676
Manufacturing	0.969	1.446	0.002	2.417
Building and Construction	1.704	1.622	0.001	3.327
Wholesale and Retail Trade	0.786	2.324	0.007	3.118
Road Transport	18.926	-	-	18.926
Australian, State and Local Govt.	0.273	1.874	0.003	2.150
Other	0.323	0.564	0.002	0.889
Not Stated	0.028	0.033	0.062	0.124
TOTAL	25.740	10.870	0.093	36.702

(a) Year ended 30 September.

Source: ABS, *Survey of Motor Vehicle Usage*, year ended 30 September 1976, Canberra 1978, Ref 9202.0, Table 13A.

TABLE V.16 - FREIGHT TASK PERFORMED BY TRUCKS, BY NUMBER OF AXLES AND AREA OF OPERATION, 1976[(a)]

(tonne-km x 10^9)

No. of Axles	Area of Operation					TOTAL
	Capital City	Provincial Urban	SUBTOTAL - Urban	Rest of State	Inter-State	All Areas
Rigid						
2	3.618	0.574	4.192	3.534	0.228	7.955
3	1.097	0.171	1.268	0.875	0.138	2.281
more than 3	0.511	0.192	0.703	0.539	0.101	1.343
not stated	0.161	0.059	0.220	0.276	0.009	0.506
SUBTOTAL						
Rigid	5.387	0.996	6.383	5.229	0.476	12.085
Articulated						
less than 5	1.917	0.531	2.448	3.926	2.513	8.887
5	1.327	0.530	1.857	3.345	2.396	7.599
6	0.745	0.487	1.232	1.879	2.554	5.665
more than 6	0.035	0.059	0.094	0.298	0.023	0.415
not stated	0.068	0.040	0.107	0.208	0.160	0.475
SUBTOTAL						
Articulated	4.092	1.647	5.739	9.656	7.647	23.041
TOTAL	9.479	2.643	12.122	14.880	8.123	35.126

(a) Year ended 30 September.

Source: ABS, *Survey of Motor Vehicle Usage*, year ended 30 September 1976, Canberra 1978, Ref. 9202.0, table 4.

TABLE V.17 - FREIGHT TASK PERFORMED BY TRUCKS, BY STATE OF REGISTRATRION AND AREA OF OPERATION, 1976[(a)]

(tonne-km x 10^9)

State of Registration	Area of Operation: Capital City	Provincial Urban	SUBTOTAL - Urban	Rest of State	Inter-State	TOTAL All Areas	(per cent)
NSW	3.365	1.461	4.826	5.006	1.950	11.783	(34)
VIC	2.523	0.456	2.979	2.858	1.853	7.690	(22)
QLD	0.992	0.472	1.464	1.676	0.522	3.663	(10)
SA	1.257	-	1.257	1.942	3.643	6.842	(19)
WA	0.986	-	0.986	2.466	0.070	3.522	(10)
TAS	0.181	0.109	0.290	0.766	0.009	1.066	(3)
NT	0.051	0.145	0.218	0.166	0.033	0.395	(1)
ACT	0.125	-	0.125	-	0.041	0.166	(1)
AUSTRALIA	9.479	2.643	12.122	14.880	8.123	35.126	(100)
(per cent)	(27)	(8)	(35)	(42)	(23)	(100)	

(a) Year ended 30 September.

Source: ABS, *Survey of Motor Vehicle Usage*, year ended 30 September 1976, Canberra 1978, Ref 9202.0, Table 3.

TABLE V.18 - TOTAL FUEL CONSUMPTION BY ROAD VEHICLES (EXCLUDING BUSES), BY STATE OF REGISTRATION, 1976[a]

(ML)

State of Registration	Type of fuel		
	Motor Spirit	Automotive Distillate	Unknown
NSW	4 270	480	73
VIC	3 700	280	14
QLD	1 900	160	7
SA	1 200	250	2
WA	1 200	140	2
TAS	350	40	1
NT	70	15	2
ACT	210	7	1
AUSTRALIA	12 900	1 370	100

(a) Year ended 30 September.

Source: ABS, *Survey of Motor Vehicle Usage*, year ended 30 September 1976, Canberra 1978, Ref 9202.0, Table 33.

TABLE V.19 - TOTAL FUEL CONSUMPTION BY ROAD VEHICLES (EXCLUDING BUSES) BY YEAR OF MANUFACTURE, 1976[a]

(ML)

Vehicle Type	Year of Manufacture								TOTAL
	Before 1955	1955-1959	1960-1964	1965-1969	1970-1974	1975	1976	Unknown	All Years
Cars and Station[b] Wagons (Tare weight - kg)									
under 1100	12	70	217	496	1 479	362	95	4	2 735
1100 and under 1300	2	14	499	1 103	1 202	253	70	2	3 146
1300 and over	7	14	68	621	2 461	608	211	3	3 992
SUBTOTAL									
Cars and Station Wagons	21	98	784	2 220	5 142	223	376	9	9 873
(per cent)	(1)	(1)	(8)	(22)	(52)	(12)	(4)	(1)	(100)
Motorcycles	1	neg	2	4	61	23	5	2	97
Utilities and[b] Panel Vans	13	21	114	384	853	266	95	4	1 750
Trucks									
petrol	16	33	108	319	594	151	67	2	1 291
other	2	3	34	219	755	263	142	5	1 422

(a) Year ended 30 September.
(b) Includes a negligible quantity of diesel fuel.

Source: ABS, *Survey of Motor Vehicle Usage* year ended 30 September 1976, Canberra 1978, Ref 9202.0, Table 34.

TABLE V.20 - AVERAGE RATE OF FUEL CONSUMPTION BY ROAD VEHICLES (EXCLUDING BUSES), BY YEAR OF MANUFACTURE, 1976[a]

(L/100 km)

Vehicle Type	Year of Manufacture								MEAN
	Before 1955	1955-1959	1960-1964	1965-1969	1970-1974	1975	1976	Unknown	All Years
Cars and Station[b] Wagons (Tare weight - kg)									
under 1100	9.7	10.2	10.3	10.0	10.2	9.9	9.6	10.2	10.1
1100 and under 1300	11.8	13.1	12.8	13.2	13.2	12.1	12.0	13.5	13.0
1300 and over	15.4	14.8	14.1	14.8	14.8	14.5	14.9	9.9	14.7
MEAN									
Cars and Station Wagons	11.3	11.1	12.1	12.7	12.8	12.3	12.6	10.7	12.6
Motorcycles	5.9	4.7	5.4	6.6	5.8	6.1	5.9	7.2	5.9
Utilities and[b] Panel Vans	14.8	14.3	13.7	14.2	14.2	14.8	14.2	15.1	14.3
Trucks									
petrol	27.2	29.1	29.7	27.5	24.2	24.8	23.4	27.8	25.5
other	37.5	34.8	35.9	38.2	42.7	43.9	43.7	51.3	42.1

(a) Year ended 30 September.
(b) Includes a negligible quantity of diesel fuel.

Source: ABS, *Survey of Motor Vehicle Usage* year ended 30 September 1976, Canberra 1978, Ref 9202.0, Table 34.

TABLE V.21 - TOTAL FUEL CONSUMPTION BY TRUCKS USED FOR BUSINESS PURPOSES, BY TARE WEIGHT[a]

Tare weight (tonnes)	Fuel Type			TOTAL
	Motor spirit (ML)	Automotive Distillate (ML)	Unknown (ML)	Energy Content[c] (PJ)
Rigid				
under 3	561.2	22.3	7.9	20.6
3 and under 4	248.2	26.6	5.2	9.8
4 and over	300.5	391.6	17.8	26.1
SUBTOTAL				
Rigid	1 109.9	440.6	30.8	56.5
Articulated				
under 9	48.6	117.9	3.0	6.3
9 and under 11	13.1	214.3	2.6	8.8
11 and over	5.2	593.1	11.4	23.3
SUBTOTAL				
Articulated	66.9	925.3	17.0	38.4
Other Truck Type Vehicles	52.2	5.2	0.7	2.0
TOTAL[b]	1 229.0	1 371.0	48.4	96.9

(a) Year ended 30 September.
(b) These totals disagree slightly with Table V.22.
(c) Energy conversion factors used are: Motor Spirit: 34.7 MJ/L; Automotive Distillate: 38.3 MJ/L. Energy conversion factors from Department of National Development, *End Use Analysis of Primary Fuels Demand, Australia, 1973-74 to 1986-87,* Canberra, 1978.

Source: ABS, *Survey of Motor Vehicle Usage,* year ended 30 September 1976, Canberra 1978, Ref 9202.0, Table 36.

TABLE V.22 - TOTAL FUEL CONSUMPTION BY TRUCKS USED FOR BUSINESS PURPOSES, BY NUMBER OF AXLES, 1976[a]

No. of Axles (tonnes)	Fuel Type: Motor spirit (ML)	Fuel Type: Automotive Distillate (ML)	Fuel Type: Unknown (ML)	TOTAL Energy Content[c] (PJ)
Rigid				
2	995.4	254.3	23.6	45.1
3	58.9	113.5	4.4	6.6
more than 3	38.6	58.6	1.6	3.6
not stated	54.9	15.9	1.5	2.6
SUBTOTAL				
Rigid	1 147.8	442.3	31.1	57.9
Articulated				
less than 5	60.4	360.6	5.6	16.1
5	4.4	307.1	5.8	12.1
6	1.2	224.6	5.0	8.8
more than 6	-	15.1	0.2	0.6
not stated	0.8	18.1	0.5	0.7
SUBTOTAL				
Articulated	66.8	925.5	17.1	38.4
TOTAL[b]	1 214.6	1 367.8	48.2	96.3

(a) Year ended 30 September.
(b) These totals disagree slightly with Table V.21.
(c) Energy conversion factors used are: Motor Spirit: 34.7 MJ/L; Automotive Distillate: 38.3 MJ/L. Energy conversion factors from Department of National Development, *End Use Analysis of Primary Fuels Demand, Australia, 1973-74 to 1986-87*, Canberra, 1978.

Source: ABS, *Survey of Motor Vehicle Usage*, year ended 30 September 1976, Canberra 1978, Ref 9202.0, Table 33, and Bureau of Transport Economics estimates.

TABLE V.23 - TOTAL BUS PASSENGERS CARRIED, AUSTRALIA, 1976[(a)]

Type of Service	Total Passengers (million)	Proportion (per cent)
Route Services		
metropolitan, provincial urban and major urban areas	495.74	63.0
intercapital routes	1.42	0.2
other areas	13.26	1.6
SUB TOTAL		
route services	(510.42)	(64.8)
School Bus Services	183.83	23.4
Charter Services	88.32	11.2
Tour Services	1.82	0.2
Other Services	2.77	0.4
TOTAL	787.16	100.0

(a) Year ended 30 June.

Source: ABS, *Survey of Bus Fleet Operations*, year ended 30 June 1976, Canberra, Ref 9203.0, Table 6.

APPENDIX VI

PIPELINES IN AUSTRALIA

INTRODUCTION

Pipelines make a specialised contribution towards the freight transport task in Australia. Their use is limited to commodities with physical characteristics which allow them to be pumped in liquid, gaseous or slurry form. While their contribution towards the total freight task is small, pipelines play a major role in transporting certain commodities, and in some cases they are the only viable mode. This supplement describes briefly the task which they performed in 1975-76 and discusses some technical aspects of pipeline operation.

The scope of this review is limited to pipelines which are used for the bulk transportation of commodities, i.e. those which can be primarily identified with the transport sector. They are a feasible option for operations of a long-term nature, involving large annual throughputs between a small number of origins and destinations. They can fulfill their task with a high degree of reliability and efficiency. This coverage includes mainly the high volume, long distance transmission of crude oil, liquid and gaseous petroleum products, and natural gas. For simplicity, reticulation and mains supply lines covering only local municipal areas are omitted. Also omitted are the numerous short branch lines associated with refinery operations. Other uses of pipelines not covered here are for water reticulation, drainage and sewerage. Many other water lines are used in hydro-electricity generation and in irrigation schemes. They are also employed in mining operations, and in grain storage and processing facilities.

PIPELINE FREIGHT TASK

Oil and Petroleum Products

The major oil pipelines in Australia are listed in Table VI.1, which shows most of these to be located in Victoria, associated with exploitation of the Bass Strait oil fields. Field gathering lines transport the crude oil from offshore platforms to the Longford stabilisation plant in Gippsland. From there the oil and gas liquids are taken by transmission lines to Long Island Point. These two types of line perform a major portion of the oil pipeline task, amounting to about 7375 million tonne-km in 1975-76. A number of lines service the three refineries in the Melbourne area, the petrochemical industry and the LPG market. In Queensland a long (306 km) line connects Brisbane with the Moonie oilfield. There are two shorter lines, one in New South Wales and one in Western Australia; details of their throughput are not available.

Natural Gas

The consumption of natural gas in Australia during 1975-76 was 5387 million cubic metres, equivalent to 213 PJ (see Chapter 2). Of this total, about 52 per cent was consumed in Victoria. Table VI.2 indicates the major natural gas lines in Australia and the task performed by them in 1975-76. The Victorian lines collectively provided the greatest throughput of any State, although the transmission lines in the other States were longer, all being over 400 km in length. The greatest single contribution to the transport task was from the Moomba-Adelaide line. A fourth category of gas lines not included above were those employed in high pressure mains supply and reticulation. These lines were generally of smaller capacity, although they totalled some 13 700 km in length(1).

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(1) Department of Minerals and Energy, Victoria; *op.cit.*, Table 58.

TABLE VI.1 - MAJOR OIL PIPELINES IN AUSTRALIA, 1976

Location	Type (see key)	Length (km)	Nominal Diameter (mm)	Commodity	1975-76 Throughput (tonnes x 10^3)	Estimated Task (tonne-km x 10^6)
VICTORIA						
Barracouta-Longford	1	53	150	Crude Oil	223	11.8
Kingfish A&B-Halibut [a]	1	29	400,500	Crude Oil	13 682	396.8
Halibut-Longford [b]	1	132	600,500	Crude Oil	20 957	2 766.3
Longford-Long Island	2	188	710	Crude Oil	17 791	3 378.6
Westernport-Altona [c]	2	82	600	Crude Oil	7 153	586.6
Altona-Geelong [c]	2	53	400	Crude Oil	3 223	170.8
Long Island-Crib Point	2	12	1050	Crude Oil	6 376	76.5
Corio-Newport	3	53	220	White Products	na	na
Corio Newport	3	56	220	Black Products	na	na
Crib Point-Dandenong	3	37	200	Products	1 065	39.4
Crib Point-Dandenong	4	39	100	LPG	20	0.8
Longford-Long Island	4	190	250	Gas Liquids	1 329	252.5
Long Island-Altona	4	79	250	Ethane		
QUEENSLAND						
Moonie-Brisbane	2	306	250	Crude Oil	60	18.3
WESTERN AUSTRALIA						
Kwinana-Kewdale	3	40	200	Products	na	na
NEW SOUTH WALES						
Clyde-Botany	4	31	850	Ethylene	na	na

(a) Kingfish A and Kingfish B are connected by a 3.7 km x 400 mm line.
(b) The submarine and overland reached of the line are 75.7 km x 600 mm and 56.4 km x 650 mm respectively.
(c) Westernport-Altona-Geelong crude pipeline (W.A.G. line).
(d) Of this, 7 225 000 tonnes came from Halibut, the rest from Kingfish.
(e) Of this, 3 391 000 tonnes went to Altona refinery, the rest continued to Geelong.
(f) Of this, 4 876 000 tonnes was shipped out from Crib Point Jetty.

Key:
1 Field gathering line
2 Crude oil transmission line
3 Refined products transmission line
4 Transfer line within refineries, wharves, terminals etc
5 LPG and ethane lines.

Source: Victoria, Department of Minerals and Energy, *The Petroleum and Gas Industry in Victoria; Statistical Reviews Nos 9 and 10*, Melbourne, 1976 and 1977.
BP Refinery (Westernport) Pty Ltd, private communication.

TABLE VI.2 - NATURAL GAS PIPELINES IN AUSTRALIA, 1976

Location	Type (see key)	Length (km)	Nominal Diameter (mm)	1975-76 Throughput ($m^3 \times 10^6$)	Estimated Task (m^3-km $\times 10^9$)
VICTORIA					
Barracouta-Longford	1	49	450	510	25.0
Marlin-Longford	1	108	500	2 049	221.3
Longford-Dandenong	2	174	750	2 367	411.9
Brooklyn-Corio	2	52	350	378	19.7
Brooklyn-Bendigo/Ballarat	2	196	150;200	77	15.1
Dandenong-Morwell	3	127	450	26	3.3
Dandenong-West Melbourne					
(North Ring)	3	82	450	437	35.8
(South Ring)	3	35	750	1 550	54.3
QUEENSLAND					
Roma-Toowoomba/Brisbane	2	438	250	251	109.9
SOUTH AUSTRALIA					
Moomba-Adelaide	2	782	550	1 502	1 174.7
WESTERN AUSTRALIA					
Dongara-Pinjarra	2	410	350	823	337.4

Key:

1 Field gathering line
2 Transmission line
3 Major supply line

Sources: Victoria Department of Minerals and Energy, *The Petroleum and Gas Industries in Victoria: Statistical Reviews Nos 9 and 10*, Melbourne. 1976 and 1977.
Gas and Fuel Corporation of Victoria, private communication.
West Australian Natural Gas Pty Ltd, private communication.

Since 1976 several major gas pipeline projects have been commenced and are now either complete or nearing completion. Foremost amongst these is the 1352 km line from Moomba to Sydney (with branches to country centres) which is expected to carry 114×10^9 cubic metres of natural gas each year over a projected 30 year life. This line was constructed by the Pipeline Authority, a statutory body set up for this purpose(1). The Gas and Fuel Corporation has extended its pipeline system to provincial towns including Albury-Wodonga. In Western Australia, the pipeline operating between Dongara and Pinjarra is serving a gas field which is expected to last until 1987.

Slurries

The single slurry pipeline presently operating in Australia carries iron ore concentrate from Savage River to Port Latta on Tasmania's north coast. The line, which has been operating since 1967, is 90 km long and is 230 mm diameter. In 1976 it transported about 2.19 million tonnes of concentrate. The Savage River line is located in particularly rugged country and it is likely that in this case the mining operation would not initially have been considered economically viable if it had to rely upon conventional modes of transport.

PIPELINE OPERATION

The energy consumption characteristics of pipelines are markedly different from those of the other transport modes in that the energy requirements depend very much on the type of freight being moved as well as on the pipe characteristics. The fluid must be pumped to overcome the pipe friction and provide the desired

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(1) The Pipeline Authority, *Fourth Annual Report 1977*, Canberra, 1978.

flow rate and delivery pressure. The required energy will vary with the fluid's dynamic viscosity, flow velocity, the pipe diameter and the hydraulic head of the system.

For natural gas pipelines, the energy expenditure may vary from nil to around 10 per cent of the energy content of the throughput(1). This is because the well head gas pressure is very important in determining whether compressor stations are needed to achieve the desired volume and output measures. In most cases the high pressures occurring in new fields are sufficient to drive the gas but as the field progressively depletes, the well head pressure declines until it proves inadequate, necessitating the installation of compressors. For example, the Moomba-Adelaide line began operations without the need for compressors but now they consume 2-3 per cent of the throughput; this is expected to rise to 5 per cent in the future to maintain adequate delivery pressure. Compressors on the Dongara-Pinjarra line in Western Australia consumed about 0.5 per cent of the throughput in 1975-76(2).

Seasonal fluctuations in demand affect the pressure in the supply lines and hence the need for compressors. The Longford-Dandenong gas line operates with compressors only during the winter months on days of high throughput. Natural gas consumption in 1978 was approximately 0.85 x $10^6 m^3$ (0.031-0.034 GJ) for 30 days of operation. Similarly the Brooklyn compressor station has a variable energy consumption depending on the system load and consumed about 0.53 x $10^6 m^3$ for the Bendigo-Ballarat line(3).

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(1) This compares favourably with transport by cryogenic tankers. About 15 per cent of the raw gas is consumed in the liquefaction plant alone and overall losses are about 20 per cent.
(2) West Australia Natural Gas Pty Ltd, private communication.
(3) Gas and Fuel Corporation of Victoria, private communication.

Table VI.3 compares typical energy intensiveness values of rail, road, and pipeline freight modes, for selected commodities. It can be seen that on an energy efficiency basis, pipelines compare very favourably with conventional transport modes for the specialised task which they perform.

TABLE VI.3 - TYPICAL ENERGY INTENSIVENESS OF TRANSPORT MODES

(MJ/tonne-km)

Commodity being transported	Mode		
	Road	Rail	Pipeline
Diesel Oil	1.60	0.33	0.01
Coal	1.37-1.83	0.32	0.02

Source: The Pipeline Authority, Canberra.

For oil lines, energy requirements will vary with the viscosity of each particular product. For low viscosity oils, centrifugal pumps, which allow greater flexibility in throughput, are used while positive displacement pumps are preferred for high viscosity oil to overcome the greater frictional resistance. In some cases, energy is expended on heating high viscosity oils to facilitate pumping.

Slurry pipelines often require energy to be spent not only on pumping but also in agitating the storage tanks, slurry drying, and water recirculation. These ancillary losses have to be included when costing the energy requirements for slurry pipeline operations.

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