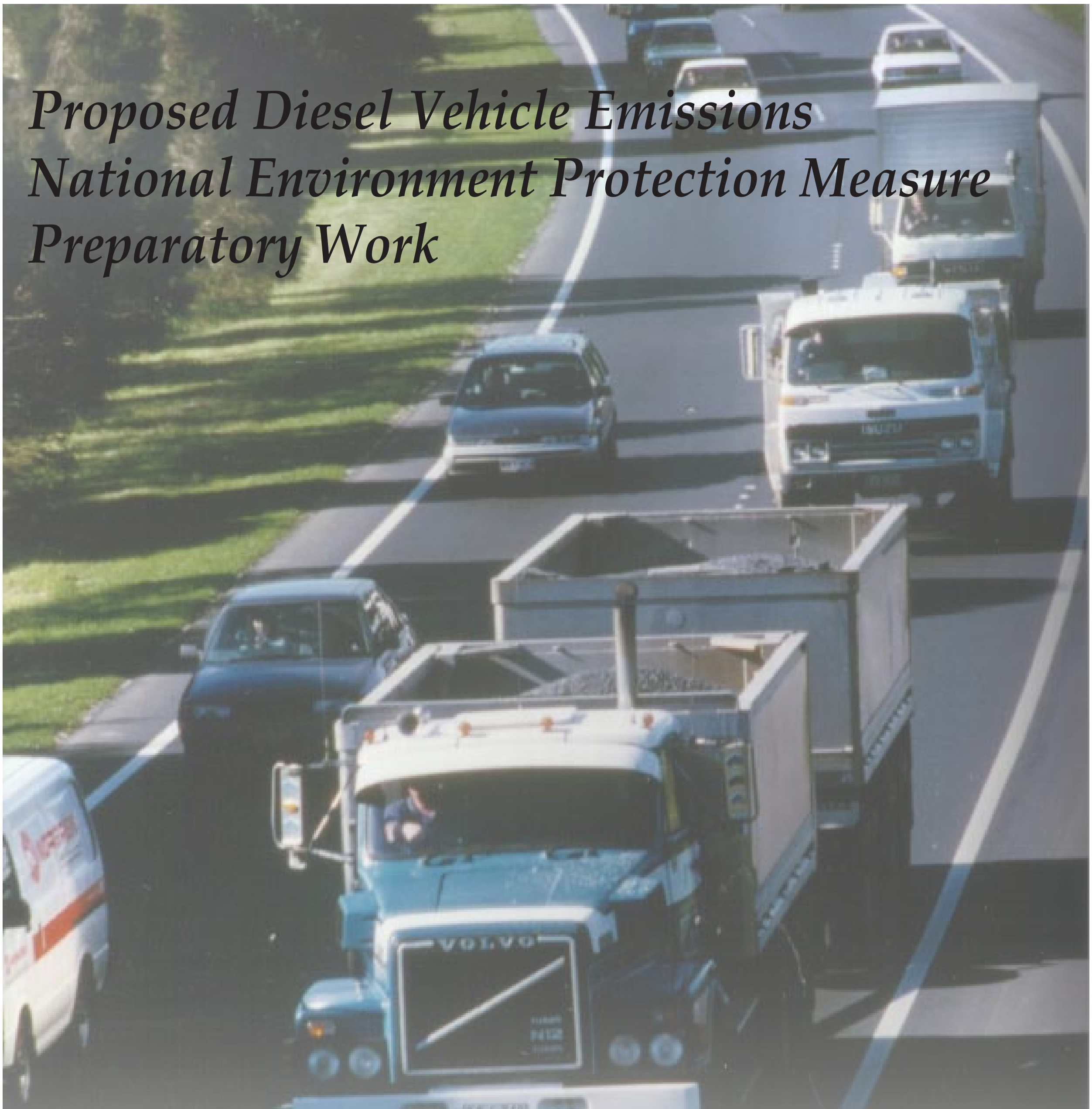
Proposed Diesel Vehicle Emissions
National Environment Protection Measure
Preparatory Work



The Australian Diesel Fleet -Existing Vehicle Characteristics and the Modelling of Transport Demand, Vehicle Populations and Emissions

November 1999

NEPC
NATIONAL ENVIRONMENT PROTECTION COUNCIL

Prepared for the

National Environment Protection Council

by

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and

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A suite of projects have been developed during the preparatory work for a proposed Diesel Vehicle Emissions National Environment Protection Measure. These projects are:

The Australian Diesel Fleet Existing Vehicle Characteristics and the Modelling of Transport Demand, Vehicle Populations and Emissions

In-Service Emissions Performance - Phase 1: Urban Drive Cycle Development

In-Service Emissions Performance - Phase 2: Vehicle Testing

In-Service Certification Correlation Studies

A Review of Dynamometer Correlations, In-Service Emissions and Engine Deterioration

In-Service Emissions Testing – Pilot Study, Fault Identification and Effect of Maintenance

Major funding for these projects has been provided by Environment Australia. The other contributing agencies are the Department of Transport and Regional Services, NSW Roads Traffic Authority and the National Road Transport Commission.

Electronic copies of these documents are available from:

National Environment Protection Council Service Corporation
Level 5, 81 Flinders Street
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Telephone: (08) 8419 1200
Facsimile: (08) 8224 0912

These documents are also available online: http://www.nepc.gov.au

EXECUTIVE SUMMARY

The brief for this project required the following;

- an assessment of the existing diesel fleet and its travel characteristics
- annual projections of vehicle numbers, travel demand and emissions of Carbon Monoxide (CO), Oxides of Nitrogen (NOx), Hydrocarbons (HC) and Particulates (PM) for the diesel fleet to the year 2015 for both metropolitan and country areas of each State and
- the impact of alternative emission and diesel fuel standards on these projections as follows:
  - Euro II / US 94 emissions standards commencing in 2002 without changes to the characteristics of diesel fuel;
  - Euro II / US 94 emissions standards commencing in 2002 together with a reduction in the sulfur content of diesel fuel from 0.15 per cent to 0.05 per cent (commencing in 2002).
  - The effect of an inspection and maintenance program on the reduction in diesel emissions
- After the terms of reference for this project were prepared these alternative scenarios became outdated because of the emission and fuel standards agreed upon in the "Measures for a Better Environment" component of the ANTS (Australian New Taxation System) II tax reform package. The differences in emissions under the following scenarios were therefore analysed:
  - Scenario I: No improvement in emission standards and no change in fuel from the existing 0.15% sulfur content. This scenario assumed that the estimated emission rates for 2002 vehicles continued as the new vehicle rates until the year 2015.
  - Scenario II: No improvement in emission standard beyond the year 2002 but a reduction in diesel sulfur content to 0.05% commencing in 2003 and to 0.005% in 2006. These low sulfur fuel scenarios used different particulate emission rates for the lower sulfur fuel but applied the same emission rates for CO, HC and NOx, as there is insufficient empirical data to reduce these pollutant emission rates because of a difference in sulfur content.
  - Scenario III: ANTS II Measures for a Better Environment including:
    - Introduction of Euro 2 for light duty vehicles (cars, LCVs) and Euro 3 or US 98 emission standards for heavy duty vehicles (buses, trucks) in 2002/3;
    - Introduction of Euro 4 or US 2004 emission standards for all vehicles in 2006/7; and
    - A change from existing 0.15% (1500 ppm) sulfur diesel to 0.05% (500 ppm) from 2003 and to 0.005% (50 ppm) from 2006.
- An extensive spreadsheet model using Microsoft Excel was developed to model the changes in transport demand and emission rates for the various scenarios. Macros were used to automate the calculation and printing of final tables and charts.

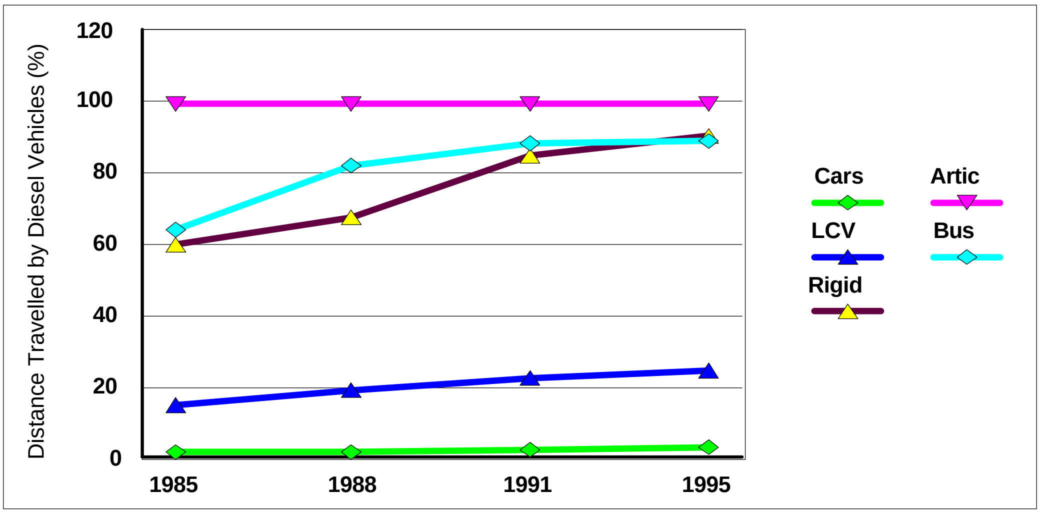
CHARACTERISTICS OF THE EXISTING DIESEL FLEET

- It was necessary to use the Australian Bureau of Statistics (ABS) vehicle categories rather than the Australian Design Rule (ADR) categories due to the availability of vehicle numbers and vehicle travel for these ABS categories.
- The number of diesel vehicles in Australia in 1995 by ABS vehicle category, as determined from adjusted Survey of Motor Vehicle Use data, is given in the following table.

Vehicle Type	Number of Diesel Vehicles	Total Number of Vehicles	Diesel Vehicle No's (% of total vehicles)
Passenger Vehicle	223,387	8,608,906	2.6
Light Commercial Vehicle	332,932	1,566,868	21.2
Rigid / Other Trucks	253,968	351,154	72.3
Articulated Trucks	56,906	57,939	98.2
Buses	37,338	45,511	82.0
Total	904,529	10,922,746	8.3

- Although the number of passenger vehicles, light commercial vehicles and rigid trucks are of the same order of magnitude, rigid trucks have a higher percentage of diesel use than these other vehicle categories. Diesel cars are mainly comprised of four-wheel drive passenger vehicles.
- A graphical summary of the historical percentage of total travel by diesel vehicles in each of these ABS vehicle categories is given below. It is seen that the use of diesel commercial vehicles has risen appreciably since 1985 and is reaching saturation for the heavy vehicle fleet of trucks and buses. The percentage of diesel travel in light commercial vehicles is continuing to increase steadily.

Percentage of Total Distance Travelled by Diesel Vehicles by Vehicle Type



- The following table gives a summary of the share of vehicle numbers, distance travelled, freight task and fuel consumed for diesel vehicles relative to the total vehicle fleet.

Summary of Diesel Vehicle Numbers, Distance Travelled, Freight Task and Fuel Consumed Relative to the Total Vehicle Fleet

Diesel Vehicle	VEHICLE NOS (% OF TOTAL)	DISTANCE TRAVELLED (% OF TOTAL)	FREIGHT TASK (% OF TOTAL)	FUEL CONSUMED (% OF TOTAL)
Passenger Vehicle	25	18	-	8
Light Commercial Vehicle	37	30	1	14
Rigid Truck	27	25	20	28
Articulated Truck	6	21	79	43
Bus	4	6	-	6
Other Truck	1	1	-	1
Totals	100	100	100	100

Articulated trucks are only a small fraction of the total diesel vehicle fleet but contribute a much larger share of the distance travelled, freight task and fuel consumed by all diesel vehicles.

A similar summary of diesel travel, fuel consumed and freight task within metropolitan areas is given in the table below.

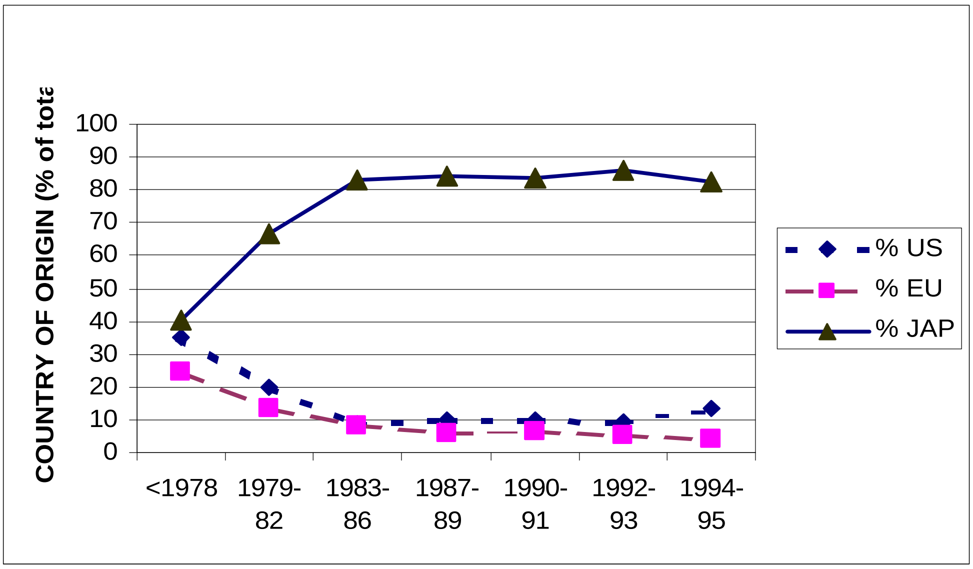
Summary of Diesel Metropolitan Distance Travelled, Freight Task and Fuel Consumed Relative to the Total Vehicle Fleet

Diesel Vehicle	DISTANCE TRAVELLED (% OF TOTAL)	FREIGHT TASK (% OF TOTAL)	FUEL CONSUMED (% OF TOTAL)
Passenger Vehicle	23	-	11
Light Commercial Vehicle	23	2	12
Rigid Truck	35	41	40
Articulated Truck	12	57	26
Bus	7	-	11
Other Truck	1	-	1
Totals	100	100	100

The above two tables show that the greatest amount of diesel fuel consumed nationally is by articulated trucks (43%) but in the capital city areas it is from rigid trucks (40%). The emission characteristics of rigid trucks will therefore be of importance for pollution studies in the capital cities.

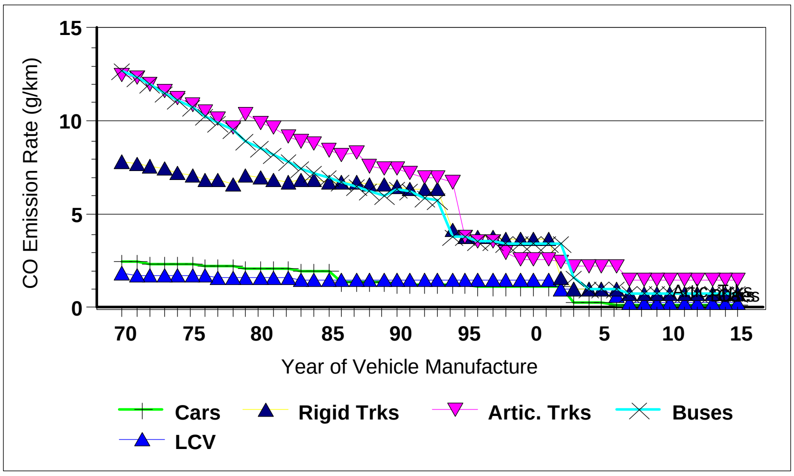
The diesel emission characteristics of new Australian diesel vehicles since 1995 are defined by ADR 70/00, which uses emission limits from standards in the US, Japan and Europe. To determine an average emission rate for all vehicles of a particular vehicle type it is therefore necessary to determine the percentage of vehicles of this type being imported from each region over time. Surveys on this matter were carried out for this project and the figure below illustrates the outcome for rigid trucks.

Rigid Trucks - Historical Variation of Country of Origin



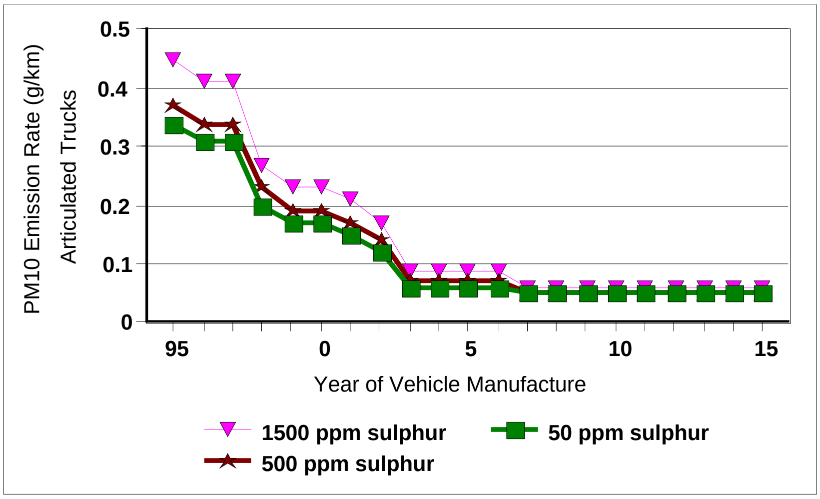
Average emission rates for each vehicle type and year of manufacture were determined by the weighting of vehicle numbers and estimated historical emission standards from each region and a typical result is given below. The significant contribution of NSW EPA to the determination of historical diesel emission rates in the various regions of the world which have been used in this study is acknowledged. The decrease in diesel CO emissions for newer vehicles is seen to be very significant and similar decreases were found for all other pollutants.

CO Emission Rates from 1970 (G/K)



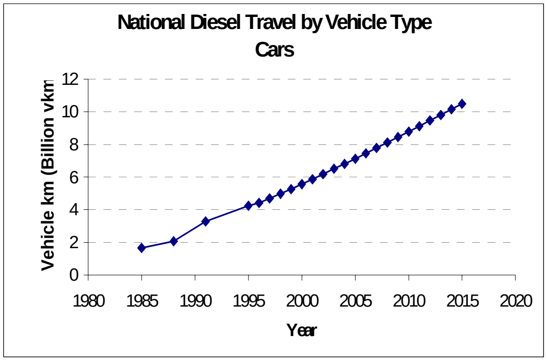
- The difference in particulate emissions for various sulfur contents in diesel fuel was also assessed. Although there is a reduction in particulate emissions with lower sulfur fuel, it is seen in the following figure that the major reductions in particulate emissions are due to the better engine technology of the newer vehicles.

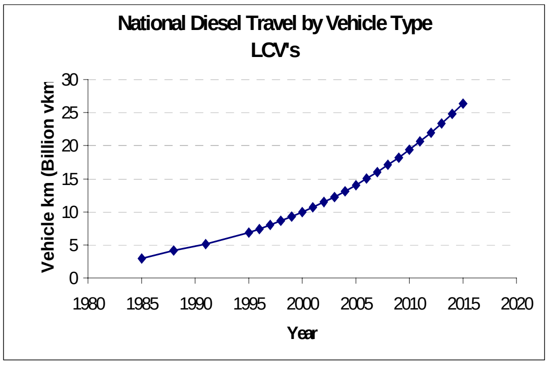
PM10 Emission Rates from 1995 (G/K)

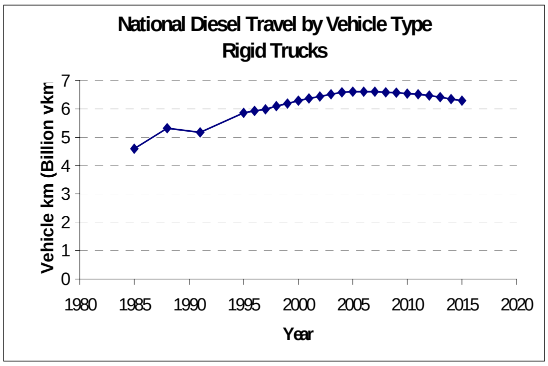


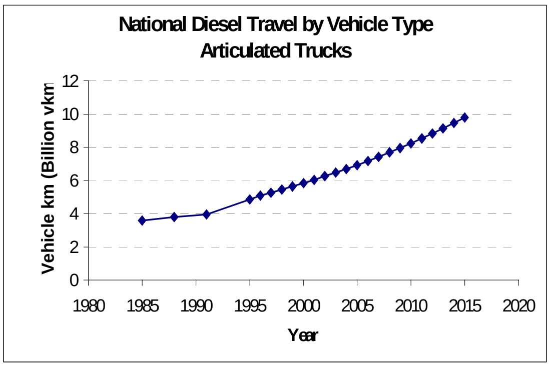
ANNUAL PROJECTIONS OF TRAVEL DEMAND AND EMISSIONS

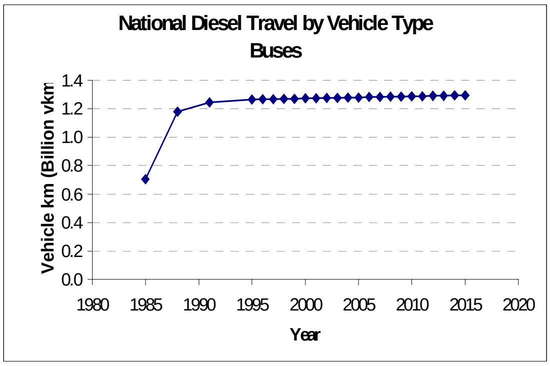
- National freight demand was determined from an econometric model incorporating economic growth (GDP) and the price of moving freight. Growth and price movements in the future, including the changes resulting from the tax reform package, were assumed and the total estimated freight demand distributed to light commercial vehicles (LCV), rigid trucks and articulated trucks in accordance with existing trends. This analysis indicated a growing market share of freight being moved by articulated trucks.
- The demand for LCV's was based on growth in the service sector of the economy, which was assumed to be related to growth in GDP, while car and bus demand were based upon existing trends. The travel demand for diesel vehicles only was then determined from this total travel demand from an analysis of existing trends for the percentage of diesel to total travel. The results for national diesel travel for the various vehicle types are given below.

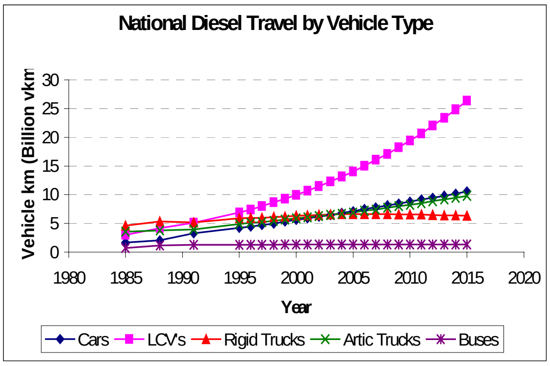












TRAVEL DEMAND FORECASTS FOR DIESEL VEHICLES

- It is evident that the largest absolute increase in travel demand will arise from LCV's followed by cars and articulated trucks.
- This diesel travel demand was used to estimate the number of vehicles in each vehicle category by assuming an annual distance travelled by each vehicle category during the forecast period. The following table shows that this methodology gives a diesel vehicle fleet that is estimated to grow from 8.3% of the total vehicle fleet in 1996 to 15% of the total fleet in 2015.
- It should be noted that estimates of vehicle numbers such as are given in this table are dependent on many different assumptions on what will happen in the future, some of which may not turn out to be correct. All of these assumptions are made very transparent in this report and the actual spreadsheet models can be altered if further data makes some of these assumptions untenable. The tabular results given below therefore embody the assumptions that have been made.

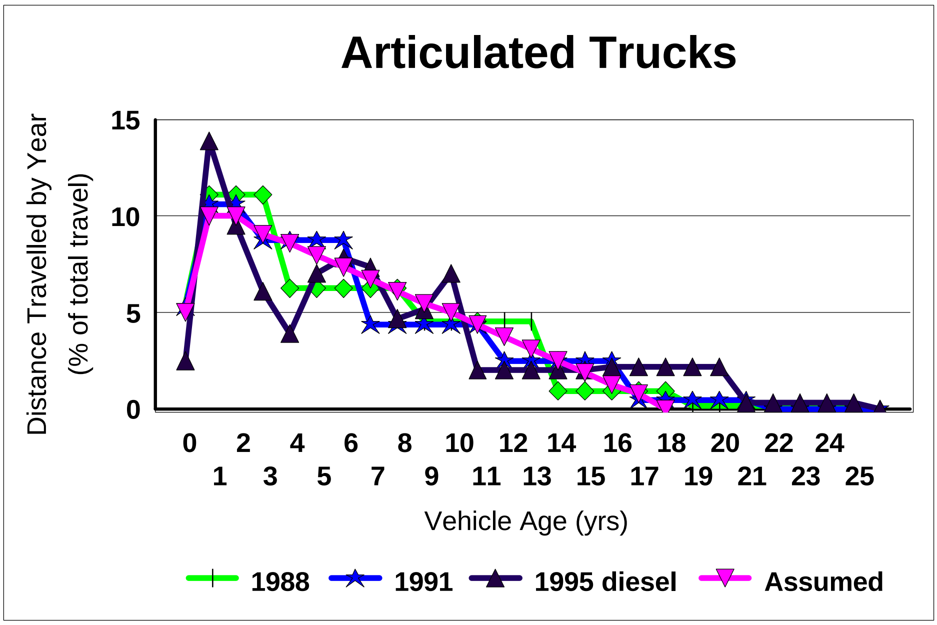
The Existing and Forecast Diesel Fleet

Vehicle Type	Total Number of all Vehicles 1995	Total Number of all Vehicles 2015	Number of Diesel Vehicles 1995	Number of Diesel Vehicles 2015
Car	8,608,906	11,021,000	223,387 (3)	556,870 (5)
Light Commercial	1,566,868	3,236,000	332,932 (21)	1,280,170 (40)
Rigid/ Other Trucks	351,154	327,690	253,968 (72)	264,360 (81)
Articulated Trucks	57,939	89,460	56.906 (98)	87,890(98)
Buses	45,511	52,170	37,338 (82)	38,180 (73)
Total	10,922,746	14,726,320	904,529 (8)	2,226,480 (15)

( ) signifies % of diesel vehicles to the total number of vehicles in this vehicle category

The national travel forecasts by vehicle type were then apportioned to State and metropolitan regions on the basis of the anticipated growth in population and economic growth in each of these States. This regional travel was then apportioned to each vehicle age according to an assumed distribution of travel with vehicle age, as shown in the figure below for articulated trucks.

Variation of Percentage of Total Travel for Articulated Trucks at Various Vehicle Ages



The estimated metropolitan and total distance travelled by the diesel vehicle fleet in Australia at various vehicle ages and at the start and end of the forecast period is given in the table below. The table indicates that although 25% of the diesel vehicle fleet is greater than 16 years old these vehicles provide only 6 to 8% of diesel travel over the analysis period.

Distance Travelled by Vehicle Age Group for Australian Diesel Fleet.

Vehicle Age (years)	% of total diesel fleet population	Metro distance travelled millions km 1996(1)	Metro distance travelled millions km 2015	Total distance travelled millions km 1995	Total distance travelled millions km 2015
0-3	26	2,417 (27)	6,354 (29)	6,296 (27)	16,374 (30)
4-6	14	1,959 (22)	4,867 (22)	4,545 (20)	12,224 (22)
7-10	18	2,096 (24)	5,097 (23)	5,699 (25)	12,646 (23
11-15	18	1,688 (19)	4,003 (18)	5,025 (22)	9,719 (17)
16-20	6	658 (7)	1,410 (6)	1,359 (6)	3,123 (6)
>20	19	67 (1)	100 (1)	293 (1)	188 (0.3)
Totals	100	8,888	21832	23,217	54,275

Notes:
1. 1996 is used for metropolitan travel as 1995 data in this format is not available for all vehicle categories.
2. ( ) signifies % of total diesel for column.

- A further analysis of the estimated distance travelled by diesel vehicles in metropolitan areas is given in the following table and indicates that by 2015 light commercial vehicles will become the dominant diesel vehicle category, accounting for 43% of the total annual distance travelled in metro areas. The percentage of distance travelled by rigid trucks is estimated to decline from 34% of all diesel travel in 1996 to 18% in 2015 as freight forwarders continue to switch to the use of articulated vehicles.

The annual emissions for any of the selected pollutants by metropolitan or non-metropolitan area and vehicle type were estimated by the following methodology:

Annual emissions = $\sum$ (vc=1 to 5) $\sum$ (myr =1976 to 2015) $\sum$ (frt =1 to 4) $\sum$ (dp = 1 to 4)
VKT (vc) X ER (vc, SCF)

Where vc = vehicle class (vc1 = cars, vc2 = LCV, vc3 = rigid trucks, vc4 = artic trucks, vc5 = buses

myr = year of manufacture (from 1976 onwards)

frt = functional road type (frt1 = freeways, frt2 = arterials, frt3 = local roads)

= rural roads only when estimating non-metropolitan emissions

dp = daily period (dp1 = AM peak, dp2 = business interpeak, dp3 = PM peak, dp4 = evening

ER = emission rate (g / km)

SCF = speed correction factor based on SCF = 1.0 at average urban average speed of 40 km / h

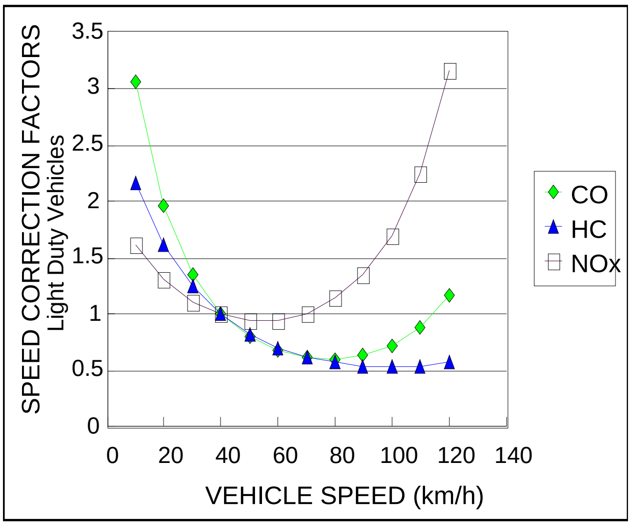
Metro Distance Travelled by Vehicle Type and Age for Australian Diesel Fleet.

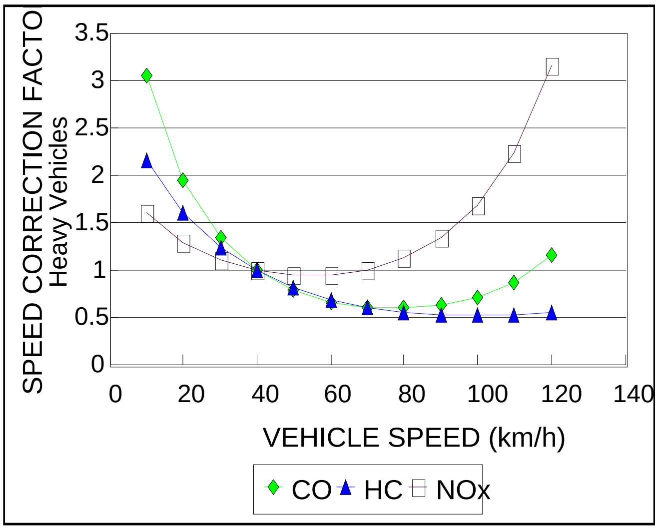
		Distance Travelled by Age Millions vehicle - km						Total metro (3)
Vehicle Type	**Year**	**0-3**	**4-6**	**7-10**	**11-15**	**16-20**	**>20**	
Passenger Vehicle	1996 (1)	598.7	452.4	471.6	378.0	142.6	---	2043.2 (23)
	2015	1605.3	1213.0	1264.5	1013.6	382.4	---	5478.8 (25)
Light Commercial	1996	668.1	477.2	487.8	371.2	112.4	4.2	2121.0 (24)
	2015	2945.9	2104.2	2151.0	1636.6	495.7	18.7	9352.0 (43)
Rigid Trucks	1996	612.1	642.7	748.0	658.0	336.7	63.0	3060.5 (34)
	2015	789.4	828.9	964.6	848.6	434.2	81.3	3946.9 (18)
Articulated Trucks	1996	354.5	248.8	244.6	165.8	22.8	---	1036.5 (12)
	2015	825.9	579.6	569.9	386.4	53.1	---	2415.0 (11)
Buses	1996	183.6	138.7	144.6	115.9	43.7	---	626.6 (7)
	2015	187.2	141.4	147.4	118.2	44.6	---	638.8 (3)
Totals	1996	2417.0	1959.8	2096.6	1688.9	658.2	67.3	8887.8
	2015	6353.7	4867.1	5097.5	4003.4	1410.0	100.0	21831.6

Note: 1. 1996 is used for metropolitan travel as 1995 data are not available for all vehicle categories.
--- signifies negligible.
( ) signifies percent of total distance travelled by all vehicles

Annual emissions in the forecast period were derived from the estimated annual distribution of travel for each vehicle type in each year, revisions to vehicle emission rates by increasing the vehicle age year by year over the forecast period and the use of a correction factor for the speeds actually occurring on the various road types over the urban and rural road network. Emission rates for various grades of low sulfur fuel were used in the appropriate scenario. The speed correction factors for the various pollutants used are given in the following figures.

Revised Mobile 5 Speed Correction Factors for Light and Heavy Duty Vehicles

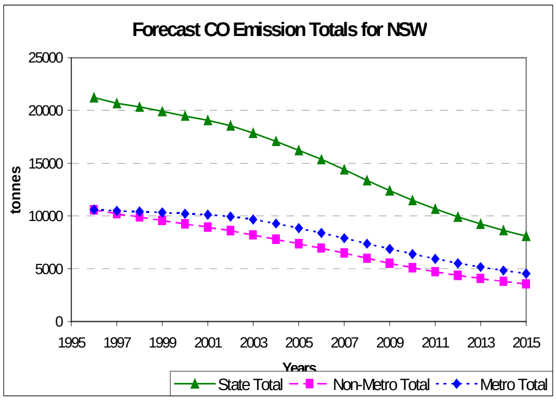


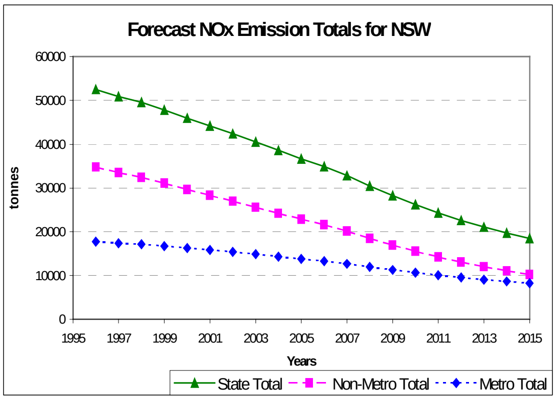


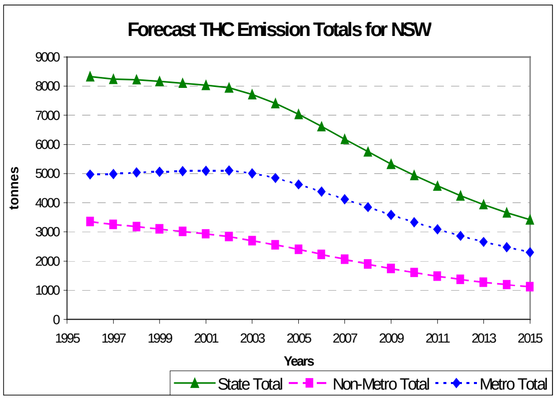
- The analysis of emissions in metropolitan areas therefore necessitated an estimation of the travel by vehicle type on each functional road type at various periods of the day and the travel speeds in each of these periods.

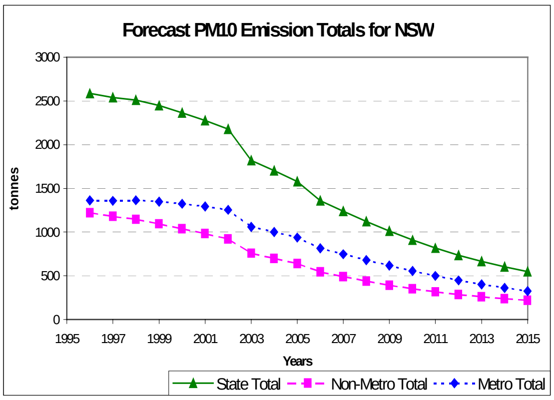
Forecast emissions in NSW for Scenario III; Measures for a Better Environment are shown in the graphs below and indicate a substantial reduction in all pollutants after the year 2003, despite the projected increase in travel demand. The greatest percentage decrease is for particulates, the sharp drop in particulate emissions in 2003 and 2006 being due to the introduction of lower amounts of sulfur in diesel at this time.

Emissions for NSW, 1995 to 2015 , Scenario III









The following table indicates just what vehicle types are contributing to the total emission load of each pollutant in metropolitan NSW. The percentage contributions of each vehicle type in both 1996 and 2015 are given so that any change can be identified.

Contribution to Emissions by Vehicle Type, Metropolitan NSW, 1996 and 2015 (% of total)

Vehicle Type	CO		NOx		HC		PM10	
	1996	2015	1996	2015	1996	2015	1996	2015
Passenger Vehicle	2.5	5.3	0.8	2.2	1.4	1.8	3.4	7.7
LCV's	5.5	10.6	2.8	7.1	2.7	3.9	7.9	11.4
Rigid Trucks	61.2	56.3	53.9	34.6	75.3	75.0	59.7	55.2
Artic. Trucks	20.2	18.4	26.5	39.7	9.8	7.2	19.4	17.0
Buses	10.6	9.4	15.9	16.5	10.8	12.1	9.6	8.7
Totals	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Tables in this report

Rigid trucks are seen to contribute the major proportion of all pollutants in metropolitan NSW in the year 2015, except for NOx, despite a reduction in the percentage of total diesel travel by this vehicle type. This is a little surprising given the reduction in demand relative to other vehcles for this vehicle type. Although there is a slight reduction in the contribution of rigid trucks, it is postulated that the percentage of emissions remains high because of the high unit emissions of these vehicles until 2002 (see **Figures 2.13 and 2.17**) and the slow turnover of the rigid truck vehicle fleet. Despite a substantial increase in travel demand for articulated trucks their percentage contribution to total pollutant emissions decreases, except for NOx. Both cars and LCV's increase their share of pollutants in 2015, mainly because of increasing travel demand but also because of the growing percentage of diesel vehicles for these vehicle types.

The changes in annual metropolitan emissions from the diesel fleet for each capital city over the forecast period from 1996 to 2015 are shown in the following table.

Significant reductions in emissions of 40 – 75% are expected from the diesel vehicle fleet over this period despite a significant growth in vehicle numbers and total annual distance travelled. The major reason for the decrease in all emissions is the better vehicle emission performance of the newer vehicles coming into the diesel fleet and the retirement of older, poorly performing vehicles.

The bigger reductions in metro emissions in some States, like SA, are due to less State transport demand in such States, less demand in metropolitan areas relative to total State demand and the mix of existing vehicle types – there is a greater reduction in emission rates for rigid trucks so that any State with a higher percentage of freight being carried by rigid trucks in 1996 will see a greater reduction in emissions.

It should be remembered that emissions from diesel vehicles contribute about 2, 20, 4 and 73% respectively of the total emissions of CO, NOx, HC and PM (EPA 1998). Any reduction in CO and HC diesel emissions will not, therefore significantly affect the total emissions for these two pollutants, which will be influenced mainly by changes in the petrol vehicle fleet.
On the other hand, diesel emissions contribute the greatest percentage (73%) of particulate emissions and this study has found that particulates have the greatest percentage reduction of all pollutants in metropolitan areas between 1996 and 2015 (between 65 and 75%). The forecasts therefore indicate that there will be a significant reduction in overall emissions and ambient levels of particulates in Australian metropolitan areas.

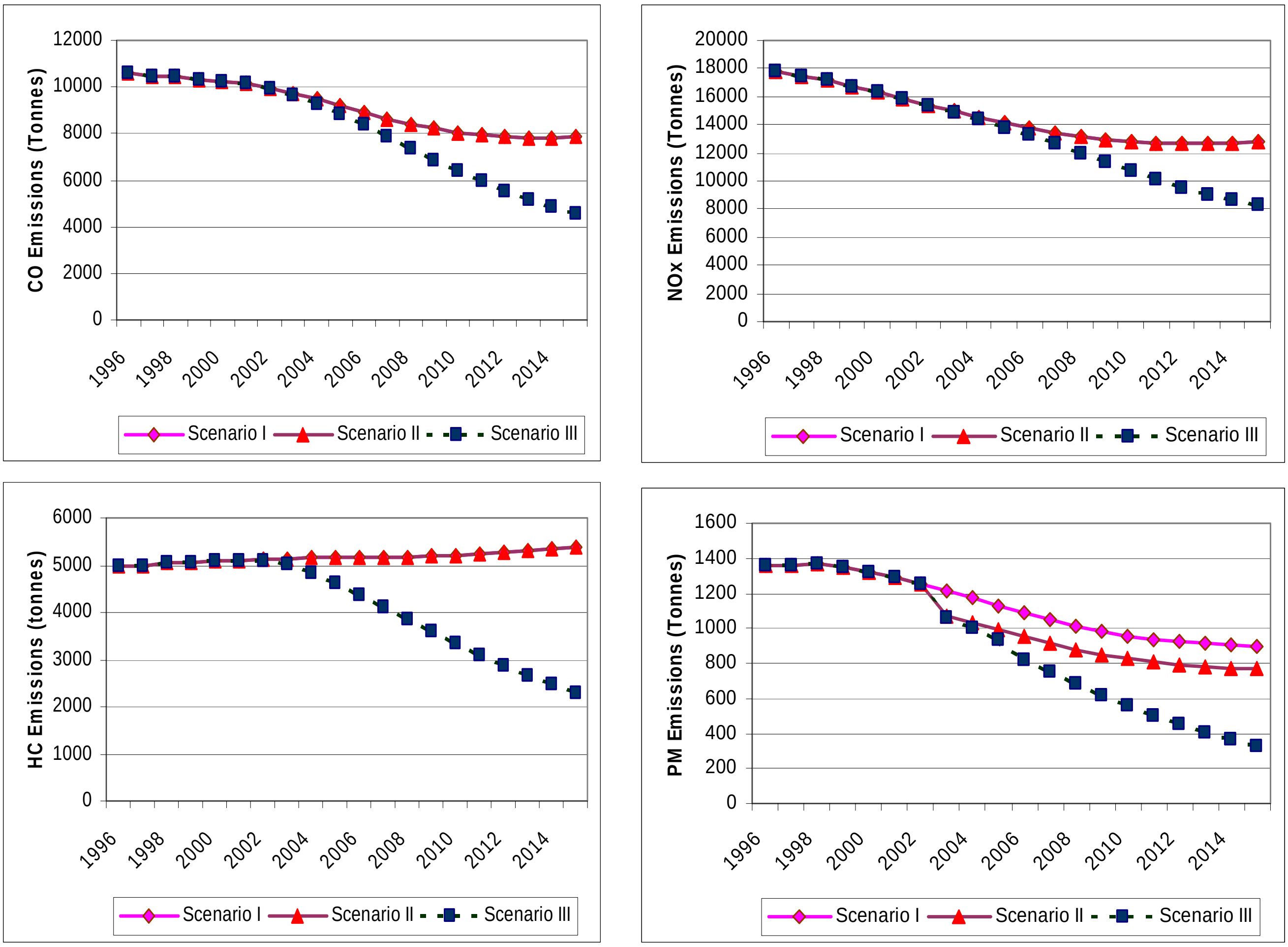
Projected Changes in Annual Metropolitan Fleet Emissions - 1996 to 2015, Scenario III

EMISSION FORECASTS (TONNES)				
	CO	**NOX**	**THC**	**PM10**
ADELAIDE 1996	2522.1	3858.9	1124.5	340.4
ADELAIDE 2015	1009.4	1318.4	475.8	83.6
NET REDUCTION (%)	**60**	**66**	**58**	**75**
BRISBANE 1996	4915.4	8791.2	2097.1	662.5
BRISBANE 2015	3003.0	5212.4	1346.3	227.6
NET REDUCTION (%)	**39**	**41**	**36**	**66**
CANBERRA 1996	549.9	1001.9	255.9	72.1
CANBERRA 2015	270.0	455.3	130.7	21.4
NET REDUCTION (%)	**51**	**55**	**49**	**70**
DARWIN 1996	348.1	540.8	150.7	48.1
DARWIN 2015	213.2	289	93.7	16.9
NET REDUCTION (%)	**39**	**47**	**39**	**65**
HOBART 1996	673.1	1147.2	285.2	86.5
HOBART 2015	334.7	604.7	152.9	23.0
NET REDUCTION (%)	**40**	**47**	**46**	**73**
MELBOURNE 1996	10442.4	16487.7	4313.5	1396.1
MELBOURNE 2015	5513.8	10479.5	2335.9	369.1
NET REDUCTION (%)	**47**	**36**	**46**	**74**
PERTH 1996	3594.4	6058.8	1572.5	491.7
PERTH 2015	2027.2	3329.8	901.9	157.2
NET REDUCTION (%)	**44**	**45**	**43**	**68**
SYDNEY 1996	10622.4	17752.9	4975.5	1362.2
SYDNEY 2015	4548.0	8276.1	2306.9	327.7
NET REDUCTION (%)	**57**	**53**	**54**	**76**

THE IMPACT OF ALTERNATIVE EMISSION AND DIESEL FUEL STANDARDS

A comparison of emissions for all four pollutants over the forecast period for metro NSW for all three scenarios is given in the figure below. There is no difference in the emissions for CO, NOx and HC between Scenarios I and II but there is a difference in particulate emissions because of the lower sulfur fuel in Scenario II. It is seen that there are appreciable reductions of all pollutants resulting from the introduction in Scenario III of Euro II through Euro IV standards, together with lower sulfur diesel fuels.

NSW Metropolitan Emissions for Different Scenarios, 1996 to 2015



Note:	Scenario I:	No improvement in emission or diesel fuel standards after 2002
	Scenario II:	Improvement in diesel fuel standards only
	Scenario III:	Improvement in diesel fuel and emission standards as per "Measures for a Better Environment"

The actual values for the emissions from all diesel vehicles in the metro areas of all States in the year 2015 for the various scenarios are given in the following table.

Difference Between Alternative Emission Scenarios in Metropolitan Areas, 2015 (tonnes)

	EMISSION FORECASTS (TONNES)			
ADELAIDE	**CO**	**NOX**	**THC**	**PM10**
SCENARIO I	1939	2148	1140	225
SCENARIO II	1939	2148	1140	184
SCENARIO III	**1009**	**1318**	**476**	**84**
BRISBANE				
SCENARIO I	5234	8312	3003	664
SCENARIO II	5234	8312	3003	490
SCENARIO III	**3003**	**5212**	**1346**	**228**
CANBERRA				
SCENARIO I	515	731	317	61
SCENARIO II	515	731	317	49
SCENARIO III	**270**	**455**	**131**	**21**
DARWIN				
SCENARIO I	377	480	209	45
SCENARIO II	377	480	209	34
SCENARIO III	**213**	**289**	**94**	**17**
HOBART				
SCENARIO I	565	972	347	74
SCENARIO II	565	972	347	50
SCENARIO III	**335**	**605**	**153**	**23**
MELBOURNE				
SCENARIO I	9756	11828	5268	1326
SCENARIO II	9756	11828	5268	874
SCENARIO III	**5514**	**10480**	**2336**	**369**
PERTH				
SCENARIO I	3748	5410	2080	470
SCENARIO II	3748	5410	2080	351
SCENARIO III	**2027**	**3330**	**902**	**157**
SYDNEY				
SCENARIO I	7845	12803	5376	1087
SCENARIO II	7845	12803	5376	770
SCENARIO III	**4548**	**8276**	**2307**	**328**

Note: Scenario I: No improvement in emission or diesel fuel standards after 2002
Scenario II: Improvement in diesel fuel standards only
Scenario III: Improvement in diesel fuel and emission standards as per "Measures for a Better Environment"

As shown in the figures that compared the various scenarios, the introduction of the emission and fuel standards in the tax reform package (Scenario III) is seen to significantly reduce all metropolitan emissions in 2015 compared to Scenarios I and II. The above table also indicates that the introduction of low sulfur fuels without any changes in emission standards will not affect the projections for CO, NOx and HC but will significantly reduce PM emissions, as shown by the difference between the values for Scenarios I and II in the last column of this table.

A review of the literature on the effect of inspection and maintenance programs (I/M) on emission performance indicated that significant reductions in pollutants will occur for HC and PM10 emissions only. The average reduction in these diesel HC and PM emissions appears to be similar to the average HC reduction in petrol engines from better engine maintenance, which is of the order of 10 – 20%.

This percentage reduction can be used as a first approximation of the benefits of an I/M program and of the deterioration in emissions performance with age. Greater accuracy in this estimation of engine maintenance effects is not considered to be realistic at the present time given the reliability of the initial estimation of emission rates and the paucity of data on the effects of maintenance programs on different vehicle types at various vehicle ages.

CONCLUSIONS

The forecasts of travel and emissions from diesel vehicles given in this report are the result of developmental work carried out to model travel demand in various States and regions by vehicle type and then to apply a distribution of travel and emission characteristics to different vehicle ages of each vehicle type.

The modelling carried out is more detailed than that generally used in emission inventory work as it provides different vehicle emission characteristics for each vehicle age, takes into account the country of origin of the various vehicle types and separately estimates emissions on three different functional road types and four daily periods in metropolitan areas where emissions are greatly influenced by vehicle speeds. The model also calculates emissions for both metropolitan and rural areas in each State.

Assumptions have been made at various points in this modelling work and may have to be changed in the light of more recent data that is being collected under other NEPC studies. All of these assumptions have been placed transparently in the spreadsheet model so that future technical developments can be incorporated in later projections of travel demand and emissions for diesel vehicles.

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ABBREVIATIONS

4WD	Four Wheel Drive Vehicle
ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
ACG	Apelbaum Consulting Group Pty Ltd
ADR	Australian Design Rules
BTCE	Bureau of Transport and Communications Economics
CNG	Compressed Natural Gas
CO	Carbon Monoxide
DTM	Dynamic Transport Management
GVM	Gross Vehicle Mass
LCV	Light Commercial Vehicles
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NSW	New South Wales
Nox	Nitrous Oxide
QLD	Queensland
SA	South Australia
SMVU	Survey Of Motor Vehicle Use
HC	Total Hydro Carbons
VIC	Victoria
WA	Western Australia

1. INTRODUCTION

The National Environment Protection Council (NEPC) is considering the development of a National Environment Protection Measure (NEPM) for the management of emissions from diesel fuelled road vehicles. In developing the NEPM, the NEPC has instigated a range of projects to *establish an improved knowledge base on the number, use, distribution and emission performance of Australia's diesel road fleet.* In addition, the work program is to *identify the factors that affect the emission performance of diesel powered vehicles.*

The first stage of the work program (Project 1) requires an assessment of the current Australian diesel fleet, including initial projections of the task undertaken by this fleet and the emissions generated to the year 2015. It is expected that the project will set the context for determining the critical factors that are affecting diesel emissions in Australia. The NEPC commissioned John Cox and the Apelbaum Consulting Group Pty Ltd (ACG) to undertake this work.

1.1 OBJECTIVES AND SCOPE OF THE ASSIGNMENT

The objectives of the assignment are to provide a comprehensive overview of the Australian diesel road fleet and to project emissions from diesel fuelled vehicles. The brief required the consultant to complete the following work activities:

- describe the number, type and use of diesel powered vehicles in Australia as at 1995 together with their associated emission design standards;
- provide annual projections of the travel and emissions of diesel vehicles by vehicle type to the year 2015 by state or territory and selected capital cities (Brisbane, Sydney, Melbourne, Adelaide and Perth). Emissions were to be estimated for carbon monoxide (CO), nitrogen oxides ($NO_{X)}$), total hydrocarbons (HC) and particulates (PM).
- assess the impact of alternative scenarios on expected diesel fleet emissions, including changes to emission standards and the sulfur content of diesel fuels.

Major changes in diesel fuel and emission standards occurred during May, 1999 as part of the ANTS II tax reform package titled “Measures for a Better Environment” and the original scenarios have been modified to incorporate these changes.

A major aspect of the project is the development of forecasting models pertaining to travel demand in the future. Best estimates of present and historical emission data have been used in the modelling but more accurate vehicle emission data will subsequently be derived from other projects within the NEPC work program. Accordingly, the emission forecasts presented in this report should be regarded as preliminary.

An Excel spreadsheet has been prepared to carry out these travel demand and emission projections and has been forwarded with this report.

1.2 OUTLINE OF THE REPORT

Chapter 2 overviews the Australian diesel fleet as of 1995 with particular reference to the transport task, fuel consumed and emission characteristics. The structure of the forecasting models is outlined in Chapter 3 while results of the travel demand forecasting are provided in Chapter 4. Chapter 5 describes the results of the emission forecasts for the alternative scenarios of various fuel and emission standards while the final chapter outlines the conclusions of the project.

2. THE AUSTRALIAN DIESEL FLEET - AN OVERVIEW AS OF 1995

There were 10,947,530 motor vehicles on register in Australia in 1995 (ABS 1997) and it is estimated that 904,529 (or 8.3 per cent of the total fleet) are diesel fuelled. The purpose of this section is to provide a comprehensive description of the Australian diesel fleet as of 1995 by vehicle type, area of operation, year of manufacture and state/territory of registration. The description includes:

- an overview of the analytical framework;
- the number of diesel fuelled vehicles;
- the total distance traveled;
- average distance traveled;
- the freight task (measured by tonne-kilometres);
- diesel fuel consumed;
- the role of 4WD vehicles within the diesel fleet.

It is generally necessary to determine the vehicle numbers, travel and freight moved by vehicles powered by all fuel types and then to differentiate those which are powered by diesel fuel. The 1995 data on vehicle numbers is analysed because these vehicle numbers have to be linked with their travel demand data and the latest survey of motor vehicle use that has been released was in 1995.

2.1 THE ANALYTICAL FRAMEWORK

The analytical framework adopted for the 1995 analysis reflects adjustments to the outcome of the Survey of Motor Vehicle Use prepared by the Australian Bureau of Statistics (ABS). These adjustments are identical to those undertaken by ACG (1997). Due care and diligence have been applied in preparing the analysis. Where a third party has provided data, no warranty is given as to the accuracy or reliability of the data.

Issues associated with the analytical framework have been addressed according to the following:

- adjustments to the ABS Survey of Motor Vehicle Use (SMVU);
- the Australian Design Rules (ADR's) and vehicle classifications;
- defining the geographical regions.

2.1.1 ADJUSTMENTS TO THE SMVU

The SMVU’s of 1995, 1991 and 1988 were revised at the "micro - level" by state, vehicle type and area of operation according to empirical fuel consumption and fuel consumption rate data. A brief description of these adjustments is provided below.

2.1.1.1 *Fuel Consumption*

Petrol

It is necessary to look at total energy consumption of the vehicle fleet in Australia in order to separate out diesel consumption. The oil industry and ABARE provided ACG with detailed statistics pertaining to petrol consumption in general and petrol consumed by the vehicle fleet, in particular. These statistics differed significantly from those presented in the SMVU. For example, the oil industry and ABARE confirmed that 17,750 million litres (ML) was consumed during 1994/95 compared with 15,268 ML estimated by the SMVU. The major discrepancy related to the consumption of unleaded petrol, with the SMVU estimating consumption at 14 per cent below that determined by the oil/petroleum industry.

Advice from ABARE and the BTCE suggested that 98 per cent of petrol consumed in Australia is attributable to the road fleet. Further, the ABS has confirmed that the discrepancy in petrol consumption related to unleaded fuelled vehicles (ACG, 1991). Accordingly, the discrepancy in petrol consumption by road vehicles was allocated to unleaded passenger vehicles.

The above adjustments were also undertaken for 1991 and 1988. Differences between industry and SMVU estimates for the 1985 survey were not considered significant to warrant further adjustment.

Diesel

ABARE advised the ACG that the SMVU might have overestimated diesel fuel consumed by the national road fleet by approximately 5 per cent in 1994/95. Accordingly, the SMVU distribution of diesel fuel consumption by vehicle type and area of operation was applied to the ABARE statistics. Similar adjustments were undertaken for 1991 and 1988 where necessary.

LPG

Advice from the Gas industry indicated that there were significant differences between the industry and SMVU estimates of LPG expended by the Australian road sector (ACG, 1997). As a result, the SMVU distribution of LPG consumption was applied to the consumption attributes provided by the Gas industry.

CNG

Apportionment of CNG consumption by vehicle type was undertaken according to vehicle data provided by the Gas industry, ACG's internal data base and various state transport authorities.

2.1.1.2 *Fuel Consumption Rate*

SMVU estimates of the fuel consumption rate for passenger vehicles as at 1995 and 1988 were similar to the empirical data prepared by Dynamic Transport Management and the CSIRO for the Federal Department Of Primary Industries and Energy (DTM, 1997). The 1991 SMVU fuel consumption rate for passenger vehicles (all fuel types) was substantially greater than that estimated by DTM. The DTM estimate of 11.5 l/100 km in 1991 was applied.

2.1.1.3 *Distance Travelled*

Revised statistics pertaining to fuel consumed and the fuel consumption rate were applied at the disaggregated level to derive distance travelled.

2.1.2 THE AUSTRALIAN DESIGN RULES AND ROAD VEHICLE CATEGORIES

Australian Design Rules 30 (subsequently 30/00) and 70/00 were introduced to reduce air pollution, by limiting the hydrocarbons, carbon monoxide, oxides of nitrogen and particulates emitted from the exhaust system of diesel fuelled vehicles (FORS, 1998).

ADR 30 was issued in February 1984 and applied to vehicles manufactured on or after 1 July 1976 (or 1 January 1985 for passenger vehicles of eight seats or more). ADR 30/00 was issued in December 1986 as a national standard and applied to vehicles manufactured on or after 1 July 1988 (or 1 March 1991 for three wheeled mopeds and motor tricycles).

In addition to ADR 30/00, ADR 70/00 was introduced to reduce pollution from motor vehicles fitted with diesel engines (FORS 1998). This design rule is binding on:

- new model vehicles with a date of manufacture on or after :
  - 1 January 1995 for some three wheeled motor tricycles, passenger cars, forward control passenger vehicles and off road passenger vehicles;
  - 1 July 1995 for some three wheeled motor tricycles, light and heavy omnibuses, and goods vehicles;
- all vehicles from:
  - 1 January 1995 for some motor tricycles and passenger vehicles;
  - 1 July 1995 for some motor tricycles, buses and goods vehicles.

The ABS vehicle classification system differs from that adopted by the ADR's in the light commercial vehicle, rigid truck and articulated vehicle categories. **Table 2.1** on the following page summarises the ABS and ADR vehicle classifications.

Table 2.1: ABS and ADR Vehicle Classifications

Vehicle Type	ABS Definition	ADR Definitions		
		ADR 30	ADRs 30/00 & 70	
			Description	*Code*
Passenger Vehicles	Constructed primarily for the carriage of up to nine persons. Includes cars, station wagons, 4WD passenger vehicles, passenger vans and camper vans.	Includes: • Passenger cars – constructed principally for the carriage of passengers; • Forward control passenger vehicle having up to nine seating positions and 3.5 GVM or less; • Multipurpose passenger cars – designed for up to 8 persons and constructed on either a truck chassis or with special features for off road operation.	Includes: • Passenger not being an off road or a forward control vehicle with up to 9 seats including driver; • Forward control passenger vehicle – not an off road vehicle having up to nine seating positions including driver; • Off road passenger vehicle – having up to 9 seating positions including driver with special features for off road use and is approved for 4WD.	MA MB MC
Motorcycles	All two and three wheeled motor vehicles.	Any motor vehicle other than a moped with up to three wheels.	Two wheeled motor vehicle with an engine capacity exceeding 50 ml or a maximum cycle speed exceeding 50 km/hr.	LC
Light Commercial Vehicles	Constructed primarily for the carriage of goods and not exceeding 3.5 tonnes GVM. Includes utilities (4WD, 2WD, single or dual cabs) and goods carrying vans.	Passenger car derivatives – a coupe utility or panel van in which the forward part of the body form and the greater part of the mechanical equipment are the same as the passenger car from the same factory.	Light Goods Vehicle – goods vehicle not exceeding 3.5 tonnes GVM.	NA

Table 2.1 (Cont'd): ABS and ADR Vehicle Classifications

<table>
<tr><th rowspan="3">Vehicle Type</th><th rowspan="3">ABS Definition</th><th colspan="3">ADR Definitions</th></tr>
<tr><th rowspan="2">ADR 30</th><th colspan="2">ADRs 30/00 & 70</th></tr>
<tr><th>Description</th><th>Code</th></tr>
<tr><td>Rigid and Other Trucks</td><td>Constructed primarily for the carriage of goods and exceeding 3.5 tonnes GVM. Includes rigid trucks equipped to tow a trailer or dolly but not a semi trailer.</td><td>Vehicles other than those above and buses and up to 4.5 tonnes GVM.</td><td>Medium Goods Vehicle – goods vehicle exceeding 3.5 tonnes GVM but not exceeding 12 tonnes GVM.</td><td>NB</td></tr>
<tr><td>Articulated Trucks</td><td>Constructed primarily for load carrying consisting of a prime mover and one or more semi trailers.</td><td>Vehicles other than those above and buses and over 4.5 tonnes GVM.</td><td>Heavy Goods Vehicle – goods vehicle exceeding 12 tonnes GVM.</td><td>NC</td></tr>
<tr><td>Buses</td><td>Constructed primarily for the carriage of passengers including passenger vehicles with 10 or more seats including the driver.</td><td>Constructed primarily for the carriage of passengers with seating for more than 8 adults (including driver). Includes the following categories:
• Up to 3.5 tonnes GVM for up to 12 seats and over 12 seats;
• Up to 4.5 tonnes GVM; and
• Over 4.5 tonnes GVM.</td><td>Includes:
• Light omnibuses incorporating
- Up to 3.5 tonnes GVM and up to 12 seats;
- Up to 3.5 tonnes GVM over 12 seats;
- Over 3.5 tonnes GVM up to 4.5 tonnes GVM;
- Over 4.5 tonnes GVM up to 5 seats; and
• Heavy omnibuses – a bus with a GVM exceeding 5 tonnes.</td><td>

MD1
MD2
MD3
MD4
MD5</td></tr>
</table>

Sources:
ABS (1996), "Survey of Motor Vehicle Use", Cat No. 9202.0
FORS (1998), pers. comm.
BTCE (1995), "Greenhouse Gas Emissions From Australian Transport - Long Term Projections", Report 88.

Given the scope of the assignment and the lack of data with respect to the distance travelled by ADR vehicle categories, it was not feasible nor practical to quantitatively differentiate the transport and fuel consumption attributes of the Australian diesel fleet according to the ADR 30/00 and/or ADR 70 vehicle classifications. As a result, the analyses reflect the ABS SMVU vehicle categories, which are passenger cars, light commercial vehicles, rigid trucks, other trucks, articulated trucks and buses.

2.1.3 AREA OF OPERATION

A key requirement of the brief is to differentiate the distance travelled, fuel consumed and emissions generated by diesel vehicles, by area of operation. Apportionment of these attributes by area of operation was undertaken by the ABS and the ACG in accordance with the Australian Standard Geographical Classification (ASGC), Edition 2.4, as detailed below:

- capital cities;
  - Sydney - area bounded by Gosford and Wyong; Hawkesbury and Blue Mountains; Campbelltown, Wollondilly and the Sutherland Local Government Areas;
  - Melbourne - area bounded by Werribee, Melton, Sunbury, Craigieburn, Whittlesea, Healesville, Warburton, Berwick, Pakenham and the whole of Mornington Peninsula;
  - Brisbane - area bounded by Caboolture, the eastern part of the Pine Rivers Shire, Redcliffe City, Redland Shire, Beenleigh, Logan City and the City of Ipswich;
  - Adelaide - area bounded by the Gulf of St. Vincent, the Gawler River and the Mount Lofty Ranges from Gawler to Bridgewater through Kangarilla and Willunga to Sellicks Beach;
  - Perth - area bounded by Yanchep and Bullsbrook; Warnbro, Keysbrook and Wooroloo;
  - Hobart - area bounded by New Norfolk, Sorell, Carlton Creek, Brighton and Snug;
  - Darwin - includes Darwin and suburbs, Palmerston and other areas north of the Howard Springs turnoff;
  - Canberra

- other urban (or provincial areas) areas;
  - New South Wales - within the areas of Newcastle, Wollongong, Bathurst-Orange, Maitland, Albury (excluding Wodonga), Wagga Wagga, Tweed Heads (excluding Gold Coast), Queanbeyan (excluding Canberra), Lismore, Coffs Harbour, Greater Taree, Hastings and Shoalhaven;
  - Victoria - within the areas of Geelong, Ballarat, Bendigo and Wodonga (excluding Albury);
  - Queensland - within the Gold Coast (excluding Tweed Heads), Sunshine Coast, Bundaberg, Rockhampton, Mackay, Townsville, Cairns and Toowoomba;
  - Tasmania - Within Launceston, Burnie, Devonport, Penguin, Ulverstone, Wynyard and Latrobe.

Other urban or provincial areas are not applicable for South Australia, Western Australia, the Northern Territory or the ACT.

- other areas of state / territory or intrastate;

- interstate.

2.2 THE NUMBER OF DIESEL VEHICLES

As of 1995, the largest component of the 904,529 strong national diesel vehicle fleet was LCVs (37 per cent of all diesel vehicles) followed by rigid trucks (27 per cent), passenger vehicles (25 per cent), articulated trucks (6 per cent), buses (4 per cent) and other trucks (1 per cent). As data pertaining to the number of vehicles is not available by area of registration the number of vehicles is only provided at the state level. **Tables 2.2 and 2.3** summarise the number of vehicles by vehicle type, year of manufacture and by state. The tables suggest the following:

- approximately 52 per cent of diesel vehicles were registered in NSW and Qld (**Table 2.2**). A further 22 per cent of diesel fuelled vehicles were registered in Victoria followed by WA (13 per cent), SA (7 per cent), Tasmania (3 per cent), NT (2 per cent) and ACT (almost 1 per cent);
- NSW and SA had a larger proportion of diesel light commercial vehicles (LCVs) and rigid trucks (combined totals of 76 per cent and 68 per cent, respectively) than the other states. However, the proportion of the total number of diesel passenger vehicles was highest in Victoria (35 per cent), Queensland (30 per cent) and WA (28 per cent) and substantially larger than those evident in NSW and SA;
- about 40% of all diesel vehicles were manufactured after 1988 (**Table 2.3).** The largest percentage of existing diesel vehicles manufactured after 1988 were LCV's (52 per cent) and passenger vehicles (52 per cent) compared with 45 per cent for buses, 26 per cent for rigid trucks, 25 per cent for articulated trucks and 23 per cent for other trucks;
- the proportion of vehicles manufactured after 1988 was highest in Victoria (53 per cent compared with the national average of 40 per cent). The lowest percentages were in NT (36 per cent) and SA (28 per cent) and Tasmania (21 per cent).

Table A-1 in **Appendix A** gives a more detailed listing of the number of vehicles by state of registration by year of manufacture and vehicle type.

Table 2.2: The Number of Diesel Vehicles by State of Registration by Vehicle Type, 1995

Vehicle Type	State								
	NSW	VIC	QLD	SA	WA	ACT	TAS	NT	AUST
Passenger	31,274	69,674	70,246	11,978	31,154	113	4,902	4,046	223,387
Row%	14	31	31	5	14	- -	2	2	100
Col %	13	35	30	18	28	2	17	24	25
Motorcycle	- -	- -	- -	- -	- -	- -	- -	- -	- -
Row %	- -	- -	- -	- -	- -	- -	- -	- -	- -
Col %	- -	- -	- -	- -	- -	- -	- -	- -	- -
Light Commercial Vehicle	98,158	49,316	88,539	26,110	46,353	3,220	14,112	7,124	332,932
Row %	29	15	27	8	14	1	4	2	100
Col %	42	25	38	40	39	48	48	42	37
Rigid Truck	80,869	52,076	53,003	18,627	29,149	2,394	7,263	3,064	246,445
Row %	33	21	22	8	12	1	3	1	100
Col %	34	26	23	28	25	35	25	18	27
Articulated Truck	14,590	16,804	11,278	5,164	6,223	280	1,629	938	56,906
Row %	26	30	20	9	11	- -	3	2	100
Col %	6	8	5	8	5	4	6	6	6
Other Truck	776	2,740	1,638	1,125	806	72	251	113	7,521
Row %	10	36	22	15	11	1	3	2	100
Col %	- -	1	1	2	1	1	1	1	1
Bus	10,574	8,168	7,267	2,668	5,046	671	1,412	1,532	37,338
Row %	28	22	19	7	14	2	4	4	100
Col %	4	4	3	4	4	10	5	9	4
Total	236,241	198,778	231,971	65,672	118,731	6,750	29,569	16,817	904,529
Row %	26	22	26	7	13	1	3	2	100
Col %	100	100	100	100	100	100	100	100	100

Notes:
Numbers may not add due to rounding.
- nil or negligible.

Sources:
Apelbaum Consulting Group.
Table A-1.

Table 2.3: The Number of Diesel Vehicles by State of Registration by Year of Manufacture, 1995

Year Of Manufacture	State								
	NSW	VIC	QLD	SA	WA	ACT	TAS	NT	AUST
To 1974	41,333	27,768	49,557	15,195	22,977	1,081	7,736	3,306	168,953
Row %	24	16	29	9	14	1	5	2	100
Col %	17	14	21	23	19	16	26	20	19
1975 - 79	9807	12,051	13,640	4,693	7,492	276	1,796	798	50,553
Row %	19	24	27	9	15	1	4	2	100
Col %	4	6	6	7	6	4	6	5	6
1980 -84	40,133	25,703	48,161	14,161	21,185	1,044	7,556	3,235	161,178
Row %	25	16	30	9	13	1	5	2	100
Col %	17	13	21	22	18	15	26	19	18
1985 -88	46,395	29,649	38,004	12,964	21,939	1,764	6,437	3,425	160,577
Row %	29	18	24	8	14	1	4	2	100
Col %	20	15	16	20	18	26	22	20	18
1989 -91	29,015	32,918	31,855	9,250	19,584	1,933	3,811	2,548	130,914
Row %	22	25	24	7	15	1	3	2	100
Col %	12	17	14	14	16	29	13	15	14
1992 -95	69,558	70,689	50,754	9,409	25,554	652	2,233	3,505	232,354
Row %	30	30	22	4	11	- -	1	2	100
Col %	29	36	22	14	22	10	8	21	26
Total	236,241	198,778	231,971	65,672	118,731	6,750	29,569	16,817	904,529
Row %	26	22	26	7	13	1	3	2	100
Col %	100	100	100	100	100	100	100	100	100

Notes:
Numbers may not add due to rounding.
- nil or negligible.

Sources:
Apelbaum Consulting Group.
Table A-1.

2.3 DISTANCE TRAVELLED

The distance travelled by diesel vehicles constitutes a minor proportion of the distance travelled by all Australian road vehicles. In 1995, the distance travelled by diesel engined vehicles totalled 23,215 million kilometres or 13 per cent of that travelled by all road vehicles. As diesel vehicles only comprised 8.3% of the total vehicle fleet this means that diesel vehicles travel larger annual distances than petrol vehicles.

Tables 2.4 to 2.7 summarise the distance travelled by diesel vehicles by area of operation and year of manufacture while **Tables A-2, A-3 and A-4** give further details at the State level. A review of these tables indicates the following:

- the proportion of distance travelled by diesel vehicles compared to the travel of the total Australian vehicle fleet differs significantly with vehicle type. The percentage is highest for the heavy vehicles, being almost 100 per cent for articulated trucks, 91 per cent for rigid trucks and 89 per cent for buses. The percentage of total travel by the lighter diesel vehicles is much lower, being 25 per cent for LCV's and 3 per cent for passenger vehicles (**Table A-2**). Figure 2.5 in Section 2.8 of this report shows the increase in the percentage of diesel travel by vehicle type over time;
- almost 30 per cent of the total national distance travelled by diesel fuelled vehicles was undertaken by light commercial vehicles (LCVs), followed by rigid trucks (25 per cent), articulated trucks (21 per cent), passenger vehicles (18 per cent), buses (6 per cent) and other trucks (almost 1 per cent) (**Table 2.4**);
- on a national basis, rigid trucks constituted 35 per cent of capital city travel by diesel fuelled vehicles followed by LCVs and passenger vehicles (23 per cent each), articulated trucks (12 per cent), buses (7 per cent), and other trucks (almost 1 per cent) (**Table 2.5**);
- diesel vehicles registered in NSW generated 26 per cent of the national diesel distance travelled compared with 25 per cent for Victoria, 24 per cent for QLD, 12 per cent for WA, 8 per cent for SA, 3 per cent for Tasmania, 2 per cent for NT vehicles and 1 per cent for vehicles registered in the ACT (**Table 2.4**);
- the proportion of travel undertaken by diesel LCVs in NSW and Qld was significantly greater than that evidenced in other states (**Table 2.4**). The proportion of total travel by diesel fuelled rigid truck vehicles in NSW and passenger vehicles in Victoria was also substantially larger than that in the other selected states;
- the distance travelled in capital cities totalled 8,432 million kilometres, or 36 per cent of total diesel travel (**Table 2.5).** This is a much lower percentage than for total vehicle travel in capital cities (54% in AGC 1997), suggesting a focus of diesel travel in rural areas;
- of the selected capital cities, Melbourne incurred the largest distance travelled by diesel fuelled vehicles (2783 million kilometres) predominantly due to the high use of diesel powered passenger vehicles (**Table 2.5**). Diesel fuelled vehicles travelled 2101 million kilometres in Sydney (the majority arising from rigid trucks) followed by Brisbane (1469 million kilometres), Perth (1055 million kilometres) and Adelaide (640 million kilometres);

Table 2.4: Total Distance Travelled By Diesel Vehicles by State of Registration by Vehicle Type, 1995 (Million Kilometres)

Vehicle Type	State								
	NSW	VIC	QLD	SA	WA	ACT	TAS	NT	AUST
Passenger	386	1,795.4	1,010.4	279.7	614	- -	70.5	72.1	4,228.1
Row %	9	42	24	7	15	- -	2	2	100
Col %	6	31	18	16	22	- -	11	17	18
Motorcycle	- -	- -	- -	- -	- -	- -	- -	- -	- -
Row %	- -	- -	- -	- -	- -	- -	- -	- -	- -
Col %	- -	- -	- -	- -	- -	- -	- -	- -	- -
Light Commercial Vehicle	2,092.9	983.4	1,990.4	462.8	886.4	68.7	232.2	151.3	6,868.1
Row %	30	14	29	7	13	1	3	2	100
Col %	35	17	36	26	32	35	38	35	30
Rigid Truck	2,008.7	1,314.1	1,285.2	384.3	611.4	67.9	135.6	57.3	5,864.5
Row %	34	22	22	7	10	1	2	1	100
Col %	33	23	23	22	22	35	22	13	25
Articulated Truck	1,184.7	1,425.5	997.1	514.8	478.5	27.7	134.7	98.4	4,861.4
Row %	24	29	21	11	10	1	3	2	100
Col %	20	25	18	29	17	14	22	23	21
Other Truck	21.6	38	42	9.5	6.6	2	4	4	127.7
Row %	17	30	33	7	5	2	3	3	100
Col %	- -	1	1	1	- -	1	1	1	1
Bus	356.5	229.4	255.5	124.1	177.1	27.9	42.3	52.8	1,265.6
Row %	28	18	20	10	14	2	3	4	100
Col %	6	4	5	7	6	14	7	12	6
Total	6,050.4	5,785.8	5,580.6	1,775.2	2,774	194.2	619.3	435.9	23,215.4
Row %	26	25	24	8	12	1	3	2	100
Col %	100	100	100	100	100	100	100	100	100

Notes:
Numbers may not add due to rounding.
- nil or negligible.

Sources:
Apelbaum Consulting Group.
Table A-2.

Table 2.5: Total Distance Travelled By Diesel Vehicles by Capital City by Vehicle Type, 1995 (Million Kilometres)

Vehicle Type	Capital City								
	Syd	Melb	Bris	Adel	Perth	Canb	Hobart	Darwin	All Aust Capitals
Passenger	154.4	1,027.1	270.3	101.5	324.3	- -	21.5	12.4	1,911.5
Row %	8	54	14	5	17	--	1	1	100
Col %	7	37	18	16	31	- -	14	13	23
Motorcycle	- -	- -	- -	- -	- -	- -	- -	- -	- -
Row %	- -	- -	- -	- -	- -	- -	- -	- -	- -
Col %	- -	- -	- -	- -	- -	- -	- -	- -	- -
Light Commercial Vehicle	370.1	456.3	505.3	215.8	231.2	51	48.4	40.6	1,918.7
Row %	19	24	26	11	12	3	3	2	100
Col %	18	16	34	34	22	39	31	42	23
Rigid Truck	1,068.4	788.1	451.4	201.7	307.3	50.6	47.5	24.4	2,939.4
Row %	36	27	15	7	10	2	2	1	100
Col %	51	28	31	32	29	39	30	26	35
Articulated Truck	305.5	342.9	150.2	50.6	97.4	4.6	19.9	6.7	977.8
Row %	31	35	15	5	10	- -	2	1	100
Col %	15	12	10	8	9	4	13	7	12
Other Truck	7.9	24	15	4.9	4.9	2	1	1	60.2
Row %	13	40	25	8	8	3	2	2	100
Col %	- -	1	1	1	1	2	1	1	1
Bus	194.8	144.6	77.2	65.7	89.7	23.1	18.8	10.6	624.5
Row %	31	23	12	11	14	4	3	2	100
Col %	9	5	5	10	9	18	12	11	7
Total	2,101.1	2,783	1,468.9	640.2	1,054.8	131.3	157.1	95.7	8,432.1
Row %	25	33	17	8	13	2	2	1	100
Col %	100	100	100	100	100	100	100	100	100

Notes:
Numbers may not add due to rounding.
- nil or negligible.

Sources:
Apelbaum Consulting Group.
Table A-2.

Table 2.6: Total Distance Travelled by Diesel Fuelled Vehicles by State of Registration by Year of Manufacture, 1995 (Million Kilometres)

Year Of Manufacture	State								
	NSW	VIC	QLD	SA	WA	ACT	TAS	NT	AUST
To 1974	91	61	54	22	53	- -	7	5	293
Row %	31	21	18	8	18	- -	2	2	100
Col %	2	1	1	1	2	- -	1	1	1
1975 - 79	413	323	242	117	209	5	31	19	1,359
Row %	30	24	18	9	15	- -	2	1	100
Col %	7	6	4	7	8	3	5	4	6
1980 -84	1,038	1,523	1,317	332	515	55	149	96	5,025
Row %	21	30	26	7	10	1	3	2	100
Col %	17	26	24	19	19	28	24	22	22
1985 -88	1,659	1,345	1,374	434	615	46	156	70	5,699
Row %	29	24	24	8	11	1	3	1	100
Col %	27	23	25	25	22	24	25	16	25
1989 -91	1,485	804	1,079	481	453	29	129	85	4,545
Row %	33	18	24	11	10	1	3	2	100
Col %	25	14	19	27	16	15	21	20	20
1992 -95	1,365	1,731	1,517	388	930	59	144	162	6,296
Row %	22	27	24	6	15	1	2	3	100
Col %	23	30	27	22	34	30	23	37	27
Total	6,051	5,787	5,583	1,774	2,775	194	616	437	23,217
Row %	26	25	24	8	12	1	3	2	100
Col %	100	100	100	100	100	100	100	100	100

Notes:
Numbers may not add due to rounding.
- - nil or negligible.

Sources:
Apelbaum Consulting Group.
Table A-3.

Table 2.7: Total Distance Travelled by Diesel Vehicles by State of Registration by Year of Manufacture - Goods Vehicles and Capital City, 1995 (Million Kilometres)

Year Of Manufacture	Capital City							
	Syd	Melb	Bris	Adel	Perth	Canb	Hobart	Darwin	All Aust Capitals
To 1974	21	19	7	7	11	- -	1	1	67
Row %	31	28	10	10	16	- -	1	1	100
Col %	1	1	1	1	2	- -	1	1	1
1975 - 79	137	154	46	30	65	3	9	3	447
Row %	31	34	10	7	15	1	2	1	100
Col %	8	10	4	6	10	3	8	4	8
1980 -84	379	326	254	102	149	38	26	20	1,297
Row %	29	25	20	8	11	3	2	2	100
Col %	9	21	23	22	23	35	23	30	22
1985	111	145	99	69	39	8	12	7	490
Row %	23	30	20	14	8	2	2	1	100
Col %	6	9	9	15	6	7	10	10	8
1986	91	101	37	29	32	6	7	2	305
Row %	30	33	12	10	10	2	2	1	100
Col %	5	6	3	6	5	6	6	3	5
1987	104	102	53	18	27	6	8	2	320
Row %	33	32	17	6	8	2	3	1	100
Col %	6	6	5	4	4	6	7	3	5
1988	123	121	68	31	40	6	7	4	400
Row %	31	30	17	8	10	2	2	1	100
Col %	7	8	6	7	6	6	6	6	7
1989	196	151	97	34	56	4	13	5	556
Row %	35	27	17	6	10	1	2	1	100
Col %	11	10	9	7	9	4	11	7	10
1990	156	131	102	27	39	4	5	5	469
Row %	33	28	22	6	8	1	1	1	100
Col %	9	8	9	6	6	4	4	7	8

Notes:
Numbers may not add due to rounding.
- nil or negligible.

Sources:
Apelbaum Consulting Group.
Table A-4.

Table 2.7 (Cont'd): Total Distance Travelled by Diesel Vehicles by State of Registration by Year of Manufacture - Goods Vehicles and Capital City, 1995 (Million Kilometres)

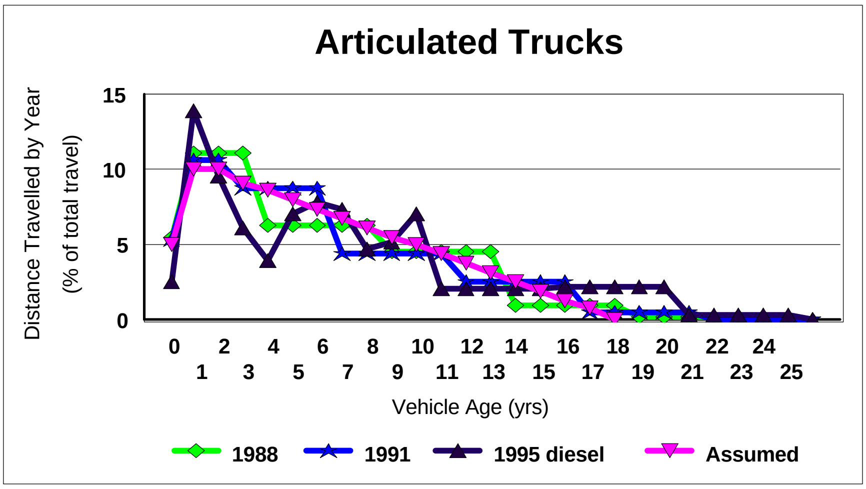
Year Of Manufacture	Capital City								
	Syd	Melb	Bris	Adel	Perth	Canb	Hobart	Darwin	All Aust Capitals
1991	87	44	80	22	29	2	8	3	275
Row %	32	16	29	8	11	1	3	1	100
Col %	5	3	7	5	5	2	7	4	5
1992	86	80	99	40	37	12	6	5	365
Row %	24	22	27	11	10	3	2	1	100
Col %	5	5	9	9	6	11	5	7	6
1993	102	82	71	25	49	10	5	5	349
Row %	29	23	20	7	14	3	1	1	100
Col %	6	5	6	5	8	9	4	7	6
1994	134	103	84	30	49	9	8	4	421
Row %	32	24	20	7	12	2	2	1	100
Col %	8	6	8	6	8	8	7	6	7
1995	16	23	10	4	14	1	- -	1	69
Row %	23	33	14	6	20	1	- -	1	100
Col %	1	1	1	1	2	1	- -	1	1
Total	1,743	1,585	1,107	468	636	109	115	67	5,830
Row %	30	27	19	8	11	2	2	1	100
Col %	100	100	100	100	100	100	100	100	100

Notes:
Numbers may not add due to rounding.
- nil or negligible.

Sources:
Apelbaum Consulting Group.
Table A-4.

- on a national basis, 47 per cent of the distance travelled by diesel fuelled vehicles was undertaken by vehicles manufactured in 1989 or after (see Table 2.6). The proportion of the distance travelled by vehicles manufactured in 1989 or after was similar to the national average in three of the selected states. The only significant deviation to the national average was in the NT where the vehicles manufactured after 1989 constituted a much larger 57 per cent of state wide travel;
- the majority (62 per cent) of national travel undertaken by diesel fuelled rigid trucks was achieved by vehicles manufactured prior to 1989, compared with 53 per cent for buses, 53 per cent for passenger vehicles and approximately 50 per cent for LCVs and articulated trucks (see **Table A-3** for All States);
- commercial vehicles (LCVs, rigid and articulated trucks) constituted 69 per cent of travel by diesel fuelled vehicles in capital cities (see **Table 2.5**). Half of this travel arises from the use of rigid trucks. The extensive use of older rigid trucks in capital cities is reflected in the comparatively low proportion of distance travelled by freight vehicles (43 per cent) manufactured in 1989 or later (see **Table 2.7**).
- The distance travelled in each vehicle age group is a critical parameter in deriving vehicle emissions as newer vehicles generate lower emissions. The non-dimensionless parameter of percentage of total travel in each year of the vehicle's life was derived from ACG adjustments to the 1988, 1991 and 1995 SMVUs. The distances travelled by vehicle age for articulated trucks as at 1985, 1988 and 1991 are shown in **Figure 2.1**.

Figure 2.1: Variation of Percentage of Travel for Articulated Trucks at Various Vehicle Ages

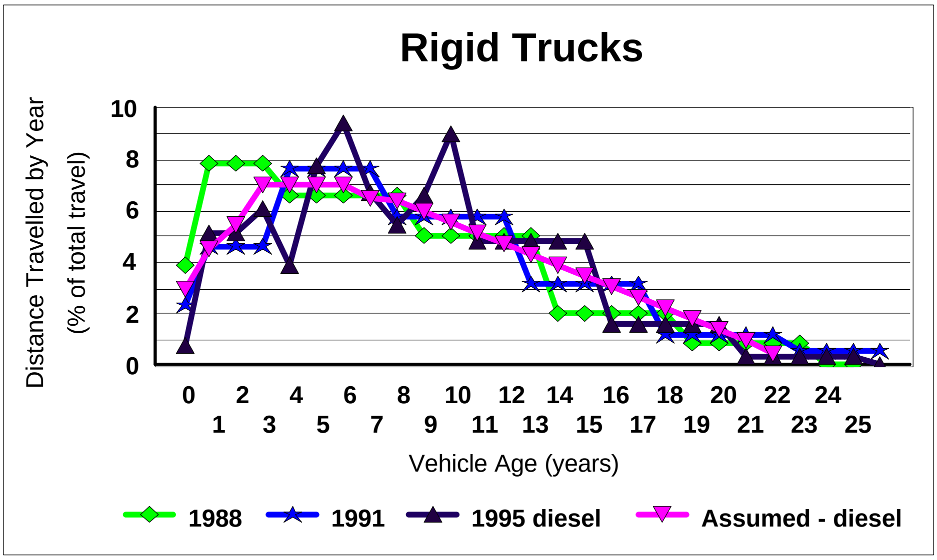


Data for distance travelled by vehicle age for all vehicles in the diesel fleet is only available for 1995. Analyses for previous years are confined to the distance travelled for all fuels by vehicle type. This is not significant for articulated trucks (see **Figure 2.1)**, as practically all articulated trucks have been diesel fuelled since 1988.

For the emission forecasts the average of all years was taken for the assumed distribution of distance travelled by vehicle age in the future. **Figure 2.1** shows that the average distribution over the vehicles lifetime gradually decreases as a percentage of total distance travelled each year until a vehicle age of 18 years is reached. This triangular pattern of travel distribution with vehicle age is known to occur when the vehicle fleet is being continuously renewed. The lower distance travelled in year 0 arises from vehicles being replaced throughout the year with the vehicles purchased later in the year travelling lower distances in this year.

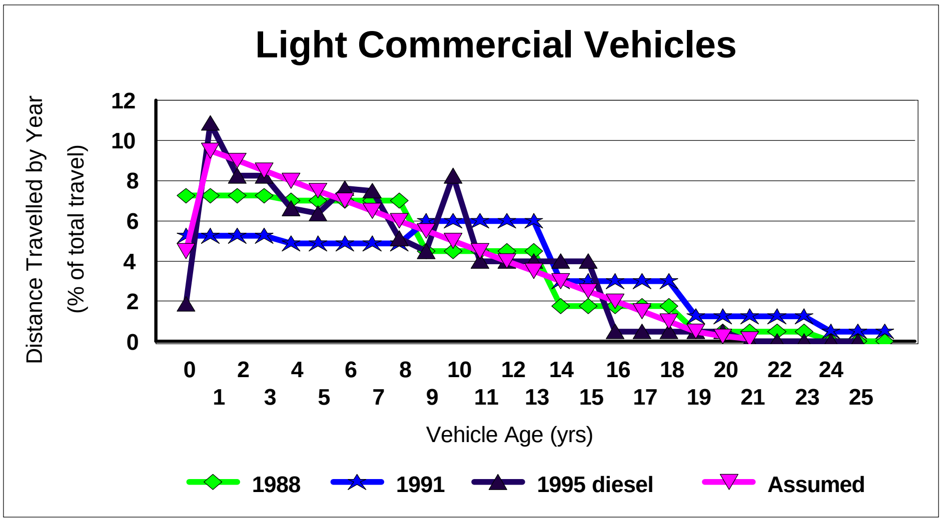
Similar figures have been prepared for other vehicle types with the distance travelled in 1988 and 1991 representing the total vehicle fleet (all fuels) while the 1995 analysis reflects the diesel fleet only. The distribution of travel for rigid trucks (**Figure 2.2**) varies substantially from other vehicle types as lower sales of new trucks have resulted in a lower percentage of travel in the first few years compared to other vehicle types. Rigid trucks also have a lower maximum percentage of distance travelled at any one vehicle age and greater travel at higher vehicle ages.

Figure 2.2: Variation of Percentage of Travel by Rigid Trucks at Various Vehicle Ages



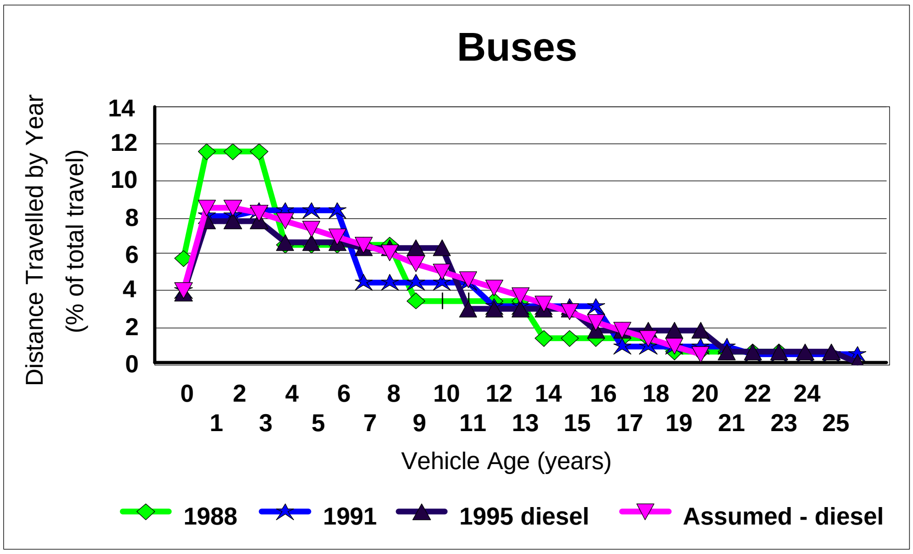
The distribution of distance travelled for diesel fuelled LCVs as at 1995 is very similar to the triangular distribution of the articulated vehicles due to the steady introduction of new vehicles. The 1991 distribution is dissimilar to the other years due to the economic recession (see Figure 2.3).

Figure 2.3: Variation of Percentage of Travel by Light Commercial Vehicles at Various Vehicle Ages



The bus distribution is very similar to that of the rigid trucks, with a reduced maximum value and greater travel at higher vehicle ages (see **Figure 2.4**).

Figure 2.4: Variation of Percentage of Travel by Buses at Various Vehicle Ages



Tables A-2 to A-4 detail the distance travelled by diesel fuelled vehicles by State, area of operation, year of manufacture and vehicle type.

2.4 AVERAGE DISTANCE TRAVELLED

The average distance travelled per vehicle by the Australian diesel fleet equated to 25,700 kilometres in 1995 (see **Table 2.8)**, some 8,700 kilometres (or 51 per cent) more than that for the national fleet (all fuels, ACG (1997)). This table also shows that diesel vehicles registered in Victoria travelled the largest average distance (29,100 kilometres) followed by the ACT (28,700 kilometres), SA (27,000 kilometres), the NT (26,000 kilometres), NSW (25,600 kilometres), QLD (24,100 kilometres) WA (23,400 kilometres) and Tasmania (20,800 kilometres).

Articulated vehicles travelled the largest average annual distance of the diesel fuelled vehicles (between 77,000 kms (WA) and 104,500 (NT)), followed by buses (between 28,200 kms (Vic) and 46,500 (SA)), rigid trucks (between 20,700 kms (SA) and 25,200 (VIC)), LCVs (between 17,700 kms (SA) and 22,500 (Qld)) and passenger vehicles (between 12,400 kms (NSW) and 25,800 (VIC)). **Table 2.8** summarises the average distance travelled by diesel vehicles registered in the selected states by vehicle type.

Table 2.8: Average Annual Distance Travelled Per Vehicle by Diesel Fuelled Vehicles by State of Registration by Vehicle Type (Thousand Kilometres)

Vehicle Type	State								
	NSW	VIC	QLD	SA	WA	ACT	TAS	NT	AUST
Passenger	12.4	25.8	14.4	23.4	19.7	- -	14.3	18	18.9
Motorcycle	- -	- -	- -	- -	- -	- -	- -	- -	- -
Light Commercial Vehicle	21.3	20	22.5	17.7	19.1	21.1	16.4	21.3	20.6
Rigid Truck	24.8	25.2	24.2	20.7	20.9	28.8	18.6	18.6	23.8
Articulated Truck	81.2	84.9	88.4	99.3	77	100	81.6	104.5	85.4
Other Truck	28.4	13.9	26.3	8	8.7	27.8	15.9	35.4	17.2
Bus	33.8	28.2	35.2	46.5	35.3	40.2	29.7	34.6	33.9
State Average	25.6	29.1	24.1	27	23.4	28.7	20.8	26	25.7

Notes:
Numbers may not add due to rounding.
- nil or negligible.

Source:
Apelbaum Consulting Group.

2.5 THE TONNE-KILOMETRE TASK

The freight task undertaken by diesel powered commercial vehicles totalled 108,369 million tonne-kilometres in 1995 which equates to almost 95 per cent of the total national road freight task. **Tables 2.9 and 2.10** detail the freight task achieved by diesel fuelled vehicles by state and in capital cities. An assessment of the tables indicates the following:

- nationally, the freight task undertaken by diesel fuelled vehicles is predominantly by articulated trucks (79 per cent) and rigid trucks (20 per cent) . Only 1 per cent of the freight task is carried out by light commercial vehicles (see **Table 2.9**);
- over 70 per cent of the national freight task undertaken by diesel fuelled vehicles is carried out in the eastern states, the vast majority (77 per cent) arising from the use of articulated trucks (see **Table 2.9**);
- the role of articulated trucks in the state wide freight task undertaken by diesel fuelled vehicles is the largest in NT (91 per cent of the state tonne-kilometre task), SA (87 per cent) and Victoria (82 per cent) (see **Table 2.9**);
- 21 per cent of the commercial freight task undertaken by diesel fuelled road vehicles in the selected states occurred in the capital cities (compare **Tables 2.9 and 2.10**);
- of the capital city freight task achieved by diesel fuelled vehicles, 33 per cent occurred in Sydney, 30 per cent in Melbourne, 16 per cent in Brisbane, 11 per cent in Perth and 6 per cent in Adelaide (see **Table 2.10)**;
- on a national basis, almost 43 per cent of the freight task undertaken by rigid trucks occurred in capital cities compared to 30 per cent for LCVs and a comparatively low 15 per cent for articulated trucks (see **Table 2.10)**;
- in Melbourne, Hobart and Darwin the proportion of the freight task undertaken by articulated trucks was higher than the national capital city average (see **Table 2.10**).

Table A-5 provides additional information pertaining to the tonne-kilometre task undertaken by diesel fuelled vehicles.

Table 2.9: Tonne-Kilometres Undertaken By Diesel Vehicles by State of Registration by Vehicle Type, 1995 (Million Tonne-Kilometres)

Vehicle Type	State								
	NSW	VIC	QLD	SA	WA	ACT	TAS	NT	AUST
Light Commercial Vehicle	325.3	181.1	382	75.8	155.5	14.6	29.3	16.8	1,180.4
Row %	28	15	32	6	13	1	2	1	100
Col %	1	1	2	1	1	2	1	1	1
Rigid Truck	6,882.1	4,656.6	4,871	1,463	2,961	231.7	537.9	253.6	21,856.8
Row %	31	21	22	7	14	1	2	1	100
Col %	28	17	21	13	21	32	21	7	20
Articulated Truck	17,859.9	22,692.5	18,280.3	9,902.6	10,704.2	477.9	1,989.2	3,425	85,331.5
Row %	21	27	21	12	13	1	2	4	100
Col %	71	82	78	87	78	66	78	93	79
Total	25,067.3	27,530.1	23,533.3	11,441.3	13,820.7	724.2	2,556.4	3,695.4	108,368.7
Row %	23	25	22	11	13	1	2	3	100
Col %	100	100	100	100	100	100	100	100	100

Notes:
Numbers may not add due to rounding.
- nil or negligible.

Sources:
Apelbaum Consulting Group.
Table A-5.

Table 2.10: Tonne-Kilometres Undertaken By Diesel Vehicles by State of Registration by Vehicle Type - Capital City, 1995 (Million Tonne-Kilometres)

Vehicle Type	State								
	Syd	**Melb**	**Bris**	**Adel**	**Perth**	**Canb**	**Hobart**	**Darwin**	**All Aust Capitals**
Light Commercial Vehicle	72.9	96.6	87.7	41.4	40.6	11.3	7.4	4.1	362
Row %	20	27	2,411	11	11	3	2	1	100
Col %	1	1	2	3	2	5	2	2	2
Rigid Truck	3,565.4	2,391.9	1,506.1	603.4	1,072.6	124	157.4	73.8	9,494.5
Row %	38	25	16	6	11	1	2	1	100
Col %	48	34	41	45	41	60	35	33	41
Articulated Truck	3,837.3	4,502.4	2,040.8	711.7	1,511.5	71.4	290.3	145.6	13,110.9
Row %	29	34	16	5	12	1	2	1	100
Col %	51	64	56	53	58	35	64	65	57
Total	7,475.6	6,990.8	3,634.6	1,356.5	2,624.7	206.7	455	223.5	22,967.4
Row %	33	30	16	6	11	1	2	1	100
Col %	100	100	100	100	100	100	100	100	100

Notes:
Numbers may not add due to rounding.
- nil or negligible.

Sources:
Apelbaum Consulting Group.
Table A-5.

2.6 DIESEL FUEL CONSUMED

Diesel fuel consumed by the Australian road fleet totalled 5,697 million litres in 1995 which equated to 23 per cent of all fuel consumed by road transport (in litre equivalents, ACG (1997)).

Tables 2.11 to 2.13 detail diesel fuel consumption within each state and selected capital cities while **Tables A-6 and A-7** in Appendix A provide further details of diesel fuel consumption by State of registration. An assessment of the tables suggests that:

- nationally 33 per cent of road based diesel fuel is expended in capital cities (compare the total fuel consumed in **Tables 2.11 and 2.12)**.
- 43 per cent of diesel fuel expended by Australian road transport was consumed by articulated trucks, followed by rigid trucks (28 per cent), LCVs (14 per cent), passenger vehicles (8 per cent) and buses (6 per cent) (**Table 2.11**);
- forty-six per cent of diesel fuel was consumed by vehicles manufactured in 1989 or later (**Table 2.13)**.
- almost 73 per cent of diesel fuel was consumed by Australian road transport in the eastern states (**Table 2.11**);
- nationally 33 per cent of total diesel consumption occurs in the capital cities (compared to 36 per cent of the total distance travelled by all diesel vehicles and 21 per cent of the freight task by diesel vehicles). On a State basis, 37 and 41 per cent of diesel fuel consumption in NSW and Victoria was expended in the respective capital cities. For Queensland, South Australia and Western Australian the corresponding consumption statistic varies between 24 and 33 per cent (see **Table 2.12**);
- nationally, almost 40 per cent of diesel fuel expended in capital cities arose from the use of rigid trucks followed by articulated trucks (26 per cent), LCVs (12 per cent), passenger vehicles and buses (11 per cent each). In Sydney, rigid trucks expend a larger proportion of fuel (predominantly at the expense of passenger vehicles and rigid trucks) than the national average while in Adelaide and Brisbane, LCVs consume a larger percentage of diesel fuel. In Melbourne, the role of passenger vehicles in urban diesel consumption is more pronounced than in other states equating to almost 19 per cent of the volume of diesel consumed by all vehicles in Victoria's capital city (**Table 2.12**);
- the proportion of diesel consumed by vehicles manufactured after 1989 in each of the states and territory was similar to the national average of 46 per cent (**Table 2.13**).

Table 2.11: Fuel Consumed by Diesel Vehicles by State of Registration by Vehicle Type, 1995 (Million Litres)

Vehicle Type	State								
	NSW	VIC	QLD	SA	WA	ACT	TAS	NT	AUST
Passenger	50.6	183.4	101.2	34.4	78.3	- -	9.6	10.5	468
Row %	11	39	22	7	17	- -	2	2	100
Col %	3	13	8	7	11	- -	6	9	8
Motorcycle	- -	- -	- -	- -	- -	- -	- -	- -	- -
Row %	- -	- -	- -	- -	- -	- -	- -	- -	- -
Col %	- -	- -	- -	- -	- -	- -	- -	- -	- -
Light Commercial Vehicle	243	112.4	209.6	56.2	114.3	7.6	26.7	18.1	787.9
Row %	31	14	27	7	15	1	3	2	100
Col %	16	8	17	11	16	16	17	15	14
Rigid Truck	531	362.3	342.2	103.9	184.9	16.2	37.2	14.3	1,592
Row %	33	23	21	7	12	1	2	1	100
Col %	35	26	28	21	26	35	24	12	28
Articulated Truck	583.9	687.9	494.3	258.6	288.2	14.3	66.8	62	2,456
Row %	24	28	20	11	12	1	3	3	100
Col %	38	48	40	52	40	31	44	52	43
Other Truck	4.9	9	8	3.3	2.5	- -	2.5	1.6	32
Row %	15	28	25	10	8	- -	8	5	100
Col %	- -	1	1	1	- -	- -	2	1	1
Bus	112.8	67.3	67.3	37	45.5	8.5	10.4	12.3	361.1
Row %	31	19	19	10	13	2	3	3	100
Col %	7	5	6	8	6	18	7	10	6
Total	1,526.2	1,422.3	1,222.8	493.4	713.7	46.7	153.1	118.9	5,697
Row %	27	25	21	9	13	1	3	2	100
Col %	100	100	100	100	100	100	100	100	100

Notes:
Numbers may not add due to rounding.
- nil or negligible.

Sources:
Apelbaum Consulting Group.
Table A-7.

Table 2.12: Fuel Consumed by Diesel Vehicles by Capital City by Vehicle Type, 1995 (Million Litres)

Vehicle Type	Capital City								
	Syd	**Melb**	**Bris**	**Adel**	**Perth**	**Canb**	**Hobart**	**Darwin**	**All Aust Capitals**
Passenger	21	108.9	27.7	12.4	41.1	- -	2.9	1.9	215.9
Row %	10	50	13	6	19	- -	1	1	100
Col %	4	19	9	9	18	- -	8	9	11
Motorcycle	- -	- -	- -	- -	- -	- -	- -	- -	- -
Row %	- -	- -	- -	- -	- -	- -	- -	- -	- -
Col %	- -	- -	- -	- -	- -	- -	- -	- -	- -
Light Commercial Vehicle	44.8	51.5	52.4	25.7	28.6	5.7	5.7	4.8	219.2
Row %	20	23	24	12	13	3	3	2	100
Col %	8	9	18	19	12	21	15	23	12
Rigid Truck	277.4	210.7	112.5	48.6	84.8	11.4	12.4	5.7	763.5
Row %	36	28	15	6	11	1	2	1	100
Col %	49	36	38	36	36	43	33	27	40
Articulated Truck	150.8	167.9	73.5	24.8	50.6	1.9	10.5	4.8	484.8
Row %	31	35	15	5	10	- -	2	1	100
Col %	27	29	25	18	22	7	28	23	26
Other Truck	2.5	6.6	3.3	1.6	1.6	- -	0.8	0.8	17.2
Row %	15	38	19	9	9	- -	5	5	100
Col %	- -	1	1	1	1	- -	2	4	1
Bus	70.1	42.6	24.6	21.8	27.5	7.6	5.7	2.8	202.7
Row %	35	21	12	11	14	4	3	1	100
Col %	12	7	8	16	12	29	15	14	11
Total	566.6	588.2	294	134.9	234.2	26.6	38	20.8	1,903.3
Row %	30	31	15	7	12	1	2	1	100
Col %	100	100	100	100	100	100	100	100	100

Notes:
Numbers may not add due to rounding.
- nil or negligible.

Sources:
Apelbaum Consulting Group.
Table A-7.

Table 2.13: Fuel Consumed By Diesel Vehicles by State of Registration by Year of Manufacture, 1995 (Million Litres)

Year Of Manufacture	State								
	NSW	VIC	QLD	SA	WA	ACT	TAS	NT	AUST
To 1974	29	19	20	7	15	- -	3	2	95
Row %	31	20	21	7	16	- -	3	2	100
Col %	2	1	2	1	2	- -	2	2	2
1975 - 79	152	130	83	43	67	2	12	7	495
Row %	31	26	17	9	14	- -	2	1	100
Col %	10	9	7	9	9	4	8	6	9
1980 -84	267	270	255	87	167	10	33	23	1,112
Row %	24	24	23	8	15	1	3	2	100
Col %	17	19	21	18	23	22	21	19	20
1985 -88	416	358	288	123	145	12	42	24	1,408
Row %	30	25	20	9	10	1	3	2	100
Col %	27	25	24	25	20	26	28	20	25
1989 -91	308	233	228	111	127	9	31	22	1,070
Row %	29	22	21	10	12	1	3	2	100
Col %	20	16	19	22	18	19	20	19	19
1992 -95	354	412	349	123	193	13	32	41	1,517
Row %	23	27	23	8	13	1	2	3	100
Col %	23	29	29	25	27	28	21	35	27
Total	1,526	1,422	1,223	493	714	47	153	119	5,697
Row %	27	25	21	9	13	1	3	2	100
Col %	100	100	100	100	100	100	100	100	100

Notes:
Numbers may not add due to rounding.
- nil or negligible.

Sources:
Apelbaum Consulting Group.
Table A-6.

2.7 THE ROLE OF 4WD VEHICLES

Data on the use of 4WDs in Australia is sparse. Accordingly, the standard errors associated with ABS data cells associated with 4WD use have, in many cases, approximated 100 per cent, thereby ensuring that an assessment of the subsequent analyses (particularly by area of operation) should be treated with caution. Notwithstanding the data limitations, it can be concluded that the total distance travelled by diesel powered 4WDs constitute a significant proportion of the distance travelled by diesel passenger vehicles (approximating 73 per cent on a national basis, all areas). The use of 4WDs in capital cities is even more pronounced than the state average, being almost 89 per cent of the distance travelled by diesel fuelled passenger vehicles.

The role of 4WDs in Sydney and Brisbane is significant, approximating 96 per cent and almost 100 per cent, respectively of the distance travelled by diesel fuelled passenger vehicles. **Tables 2.14 and A-8** provide further detail of distance travelled by diesel 4WDs.

Table 2.14: Distance Travelled by Diesel 4WD Passenger Vehicles by State of Registration (Million Kilometres)

Area Of Operation	State								
	NSW	VIC	QLD	SA	WA	ACT	TAS	NT	AUST
Capital City	148.3	889.7	270.1	84.5	271.5	- -	29.2	11.9	1,705.2
Row %	9	52	16	5	16	- -	2	1	100
Col %	50	76	34	40	52	- -	73	17	55
Total	297.2	1,167.6	794	210.7	519.7	1	40.1	69.6	3,099.9
Row %	10	38	26	7	17	- -	1	2	100
Col %	100	100	100	100	100	100	100	100	100

Notes:
Numbers may not add due to rounding.
- nil or negligible.

Sources:
Apelbaum Consulting Group.
Table A-8.

2.8 SUMMARY OF DIESEL VEHICLE CHARACTERISTICS

The number of diesel powered vehicles in Australia in 1995 as a percentage of the total vehicles in this vehicle category is given in table 2.14a.

Table 2.14a: Summary of Diesel Vehicle Numbers

Vehicle Type	Number of Diesel Vehicles	Total Number of Vehicles	Diesel Vehicle No's (% of total)
Passenger Vehicle	223,387	8,608,906	2.6
Light Commercial Vehicle	332,932	1,566,868	21.2
Rigid / Other Truck	253,968	351,154	72.3
Articulated Truck	56.906	57,939	98.2
Bus	37,338	45,511	82.0
Total	904,529	10,922,746	8.3

The distribution (%) of the diesel vehicle numbers, distance travelled, freight task and fuel consumed at a national level and in our capital cities is given in Tables 2.15 and 16 following.

Table 2.15: Distribution of National Diesel Vehicle Numbers, Travel, Freight Task and Fuel Consumed

Diesel Vehicle	Vehicle Nos (% of Total)	Distance Travelled (% of Total)	Freight Task (% of Total)	Fuel Consumed (% of Total)
Passenger Vehicle	25	18	-	8
Light Commercial Vehicle	37	30	1	14
Rigid Truck	27	25	20	28
Articulated Truck	6	21	79	43
Bus	4	6	-	6
Other Truck	1	1	-	1
Totals	100	100	100	100

Table 2.16: Distribution of Capital City Diesel Travel, Freight Task and Fuel Consumed

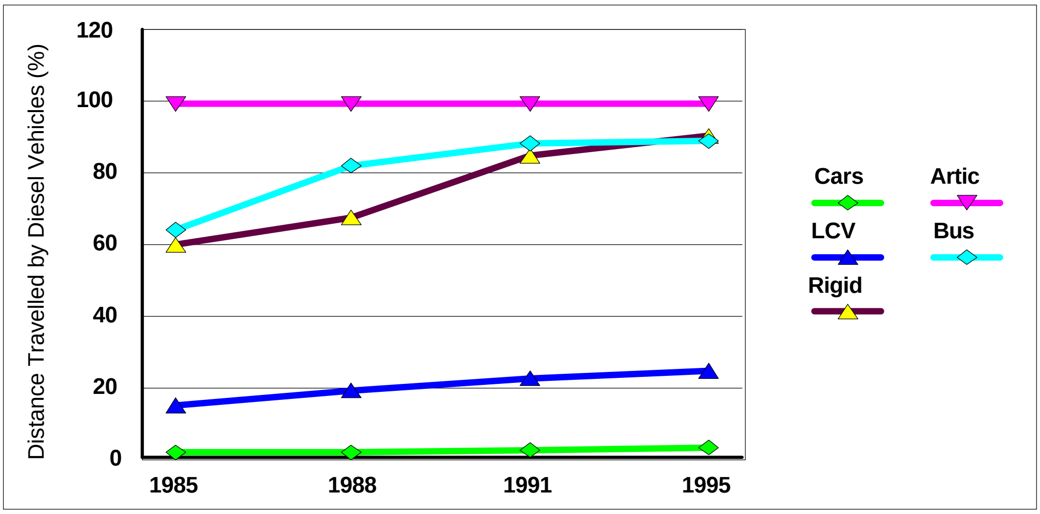
Diesel Vehicle	Distance Travelled (% of Total)	Freight Task (% of Total)	Fuel Consumed (% of Total)
Passenger Vehicle	23	-	11
Light Commercial Vehicle	23	2	12
Rigid Truck	35	41	40
Articulated Truck	12	57	26
Bus	7	-	11
Other Truck	1	-	1
Totals	100	100	100

In conclusion, the greatest amount of diesel fuel consumed nationally is by articulated trucks (43%) while in the capital city areas it is by rigid trucks (40%).

2.9 DIESEL EMISSION CHARACTERISTICS

Diesel powered vehicles have gained an increasing share of the total distance travelled by all vehicles, as shown in **Figure 2.5**.

Figure 2.5: Percentage of Total Distance Travelled by Diesel Vehicles by Vehicle Type



Source: Tables in this report

The above figure shows that between 90 and 100% of the heavy vehicle fleet (articulated trucks, rigid trucks and buses) are now diesel powered while the share of diesel LCV's is increasing[1]. A major difference between the Australian and European vehicle fleets is the very low percentage of diesel cars in Australia (3 per cent) compared to 23 per cent in Europe (www.dieselnet.com update of 23 November, 1998). This percentage of diesel cars in Europe is estimated to increase to 33 per cent in 2005 and to have much reduced emissions through improved diesel engine technology.

The primary reason for the popularity of diesel engines in Australia is their lower maintenance costs and a 20 to 30 per cent greater fuel efficiency compared to similar petrol fuelled vehicles (Houghton 1994). Diesel engines also have lower carbon monoxide (CO) and total hydrocarbon (HC) emission levels than petrol engines but higher oxides of nitrogen (NOx) and particulate (PM10 and PM2.5) levels. It has been estimated that the higher global warming factors for carbon monoxide and hydrocarbons cause 20 - 40% lower overall greenhouse gas emissions for diesel cars compared with petrol cars (Grant 1992).

During the 1990s there has been considerable development work to improve the performance of diesel engines including turbo charging, more controlled injection techniques, particulate traps and catalysts to reduce emissions. London Transport has installed catalysts on about half of their diesel buses and, together with the use of ultra low sulfur diesel have reduced bus emissions to below that of CNG buses with an oxygen catalyst (Dickson-Simpson 1998).

[1] Australia Post has converted all of its LCV's to diesel and their entire fleet is now diesel fuelled.

A higher sulfur content in diesel fuel increases metal sulphate particulate emissions. Accordingly, the US EPA has imposed strict limits on the sulfur content of diesel reducing the sulfur content of diesel fuel to 0.05% in 1993 (500 ppm). The 0.05% sulfur content has since become the standard in the UK and Europe as a result of health concerns associated with high sulfur diesel fuel.

Although the current Australian standard is 0.5% sulfur, the weighted average from eight Australian refineries in 1996 suggested that the sulfur content of Australian diesel fuel is 0.15% (Australian Transport News March 27, 1998). Bass Strait oil crude was found to give a lower diesel sulfur content than Middle Eastern crude. Due to differences in sulfur contents and the standard of diesel fuel used, there needs to be some caution when translating actual diesel emission levels from road vehicles in other countries to that of Australia.

The recent tax reform package will result in the following new standards for diesel fuel in Australia:

- Voluntary introduction of 0.05% (500 ppm) sulfur diesel in urban areas from the year 2000;
- Compulsory introduction of 0.05% (500 ppm) sulfur diesel for road transport by the end of the year 2002;
- Differential pricing (through excise) in the years 2003, 2004 and 2005 to facilitate the introduction of very low 0.005% sulfur fuel (50 ppm); and
- Compulsory introduction of very low sulfur fuel in the year 2006.

2.10 DIESEL EMISSION STANDARDS

ADR 30/00 set limits for smoke from diesel engines. ADR 70/00 for diesel powered vehicles has applied to new vehicles since July 1995 and allows compliance with acceptable overseas standards such as the US EPA 1991, Euro I (ECE/EU 1992) and the Japanese 1993/94 standard (at that time). The emission levels for these various overseas standards are shown in **Table 2.17**. Comparisons of emission rates should be undertaken with caution due to differing testing techniques in these various countries.

Truck manufacturers are now importing trucks that have better emission characteristics than those required by Australian emission standards as they are compliant with the newer standards introduced by the country of origin of the vehicle. **Table 2.18** summaries the emission standards of trucks imported into Australia during the past ten years. Further descriptive material that has been obtained from interviews with commercial vehicle suppliers is given in **Appendix B**.

Table 2.17 Summary of Diesel Emission Limits Imposed by the Various Standards Adopted in ADR 70/00

STANDARD & VEHICLE TYPE	LIMITS ON EMISSIONS *				
	CO	*HC*	*NOx*	*HC + NOx*	*PARTICULATES*
PASSENGER CARS					
US 1991	2.1g/km	0.26 g/km	0.63 g/km		0.12 g/km
ECE R83/01	2.72 g/km			0.97 g/km	0.14 g/km
Japan 1993/94	2.7 g/km	0.62 g/km	0.72 g/km		0.34 g/km
LIGHT COMMERCIALS * **					
US 1991 < 1.7 t	6.2 g/km	0.5 g/km	0.75 g/km		0.16 g/km
> 1.7 t	6.2 g/km	0.5 g/km	1.1 g/km		0.08 g/km
ECE R83/01**	2.72 g/km			0.97 g/km	0.14 g/km
ECE R49/02** <85kW	4.5 g/kWh	1.1 g/kWh	8.0 g/kWh		0.61 g/kWh
>85kW	4.5 g/kWh	1.1 g/kWh	8.0 kWh		0.36 g/kWh
JAPAN 93/94 < 1.7 t	2.7 g/kWh	0.62 g/kWh	0.84 g/kWh		0.34 g/kWh
> 1.7 t	2.7 g/kWh	0.62 g/kWh	1.82 g/kWh		0.43 g/kWh
HEAVY VEHICLES					
US 1991	11.0 g/kWh	1.0 g/kWh	6.7 g/kWh		0.24 g/kWh
ECE R49/02	4.5 g/kWh	1.1 g/kWh	8.0 g/kWh		0.36 g/kWh
JAPAN 1993/94 -direct injection engines	9.2 g/kWh	3.8 g/kWh	7.8 g/kWh		0.96 g/kWh
- indirect injection	9.2 g/kWh	3.8 g/kWh	6.8 g/kWh		0.96 g/kWh

Notes:

* The emission limits in the various standards are not directly comparable due to the different test methods.

** ECE R83/01 is equivalent to EEC Directive 91/441/EEC
ECE R49/02 is equivalent to EEC Directive 91/542/EEC

*** There are a range of light commercial vehicles where manufacturers have the option of certifying to either R49/02 or R83/01 under specified conditions.

Only the US standards have durability requirements. The US 1991 standards require that the limits be met for the useful life of the vehicle in years or kilometers (whichever comes first) as follows:

Passenger Cars 5 years/ 80,000 km

Light Commercials 11 years/ 190,000 km

Heavy Duty Vehicles 8 years/ 170,000 or 300,000 or 465,000 km depending on vehicle weight.

Table 2.18: Emission Standards of Trucks Imported into Australia by Country of Origin (Historical and Forecast)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Engine Makers											
USA											
Caterpillar		**EPA 91>**			**EPA 94>**				**EPA 98>**		
Cummins						**EPA 91>**		**EPA 94>**		**EPA 98>**	
Detroit Diesel						**EPA 91>**			**EPA 94>**		
Mack Trucks						**EPA 91>**			**EPA 94>**		
EUROPE											
Iveco	**Euro 1>**							**Euro 2>**			**Euro 3>**
M.A.N.							**Euro 1>**				
Mercedes-Benz	**Euro 1>**							**Euro 2>**			
Perkins							**Euro 1>**				
Scania	**Euro 1>**							**Euro 2>**			
Renault							**Euro 1>**				
Volvo							**Euro 1>**				
JAPAN											
Hino											
Isuzu							**Euro 1>**				
Mazda (+Ford Trader)							**EEC 91**				
Mitsubishi							**Japan 93/94**				
Nissan UD							**Euro 1>**			**Euro 2>**	
Toyota							**Japan 93/94**				

Source: Interviews with engine manufacturers (Appendix B)

In 1998, US manufactured trucks imported into Australia complied with either EPA 1994 or EPA 1998. During the same period, most European trucks imported into Australia complied with Euro II. The Japanese emission standards were changed in the 1990's to better reflect European test conditions. Most Japanese trucks now being imported to Australia comply with Euro I standards.

Summaries of the diesel emission standards for cars, LCVs and heavy vehicles (rigid trucks, articulated trucks and buses) manufactured in the US, Europe and Japan are given in **Tables 2.19, 2.20 and 2.21,** respectively. The recent agreement of future emission standards arising from the recent Australian tax reform package is given in **Table 2.22**.

Table 2.19: Emission Standards for Diesel Cars (g/k)

	CO	HC + NOx	NOx	PM
(A) European				
1991 - 91/441/EEC	3.16	1.13		0.18
1994 - 94/12/EC	1	0.7		0.08
Euro 2 * - Otto 1996 - IDI Diesel	2.2 1.0	0.5 0.7		 0.08
Euro 3 * - Otto 2000 - Diesel	2.2 1.0		0.14 0.40	 0.05
2005 (Proposed)	0.5	0.3	0.25	0.03

Source:
CONCAWE 1995.
Hausberger and Sturm (1998)

* Uses NEDC (New European Driving Cycle = R15 + EUDC) but without warm-up.

Table 2.20: Emission Standards for Light Commercial Vehicles (g/k)

	CO	HC + NOx	PM
(A) European			
1993 - 93/59/EEC			
< 1.15 t	3.16	1.13	0.18
1.15 - 1.70 t	6	1.6	0.22
> 1.70 t	8	2	0.29

Source:
CONCAWE 1995.

Table 2.21: Emission Standards for Heavy Vehicles (g/kwh)

Type	CO	HC	NOx	PM
(A) European				
1. As of 1/7/1988	11.2	2.4	14.4	Smoke: ECE-R24 72/306/EWG
2. Euro I 1/7/1992	4.5	1.1	8.0	0.36 (0.4 > 85 kw) 0.612 (0.68 ≤ 85 kw)
3. Euro II 1/10/1995	4.0	1.1	7.0	0.15
4. Euro III 2000	2.0	0.6	5.0	0.10
(B) United States				
1. EPA On Highway Standards				
1990	20.8	1.7	8.0	0.80
1991	20.8	1.7	6.7	0.34
1994	20.8	1.7	6.7	0.13
1998	20.8	1.7	5.4	0.13
2004 (Proposed)	20.8.	1.7	2.7	0.13
(C) Japan				
1995	9.2	3.8	7.8	0.96
1998 (target)			4.5	0.3

Notes:
n.a. - not available.
avg - average.
- nil or negligible.

Sources:
ACG (1995)
CONCAWE 1995.
Faiz et al 1996.

Table 2.22: Summary Table of Proposed ADR Amendments for Vehicle Emissions

ADR Categories			Equivalent ECE Category	Applicable New ADR (1,2)	2002/3 (Diesel Vehicles)	2003/4 (Petrol Vehicles)	2005/6 (Petrol Vehicles)	2006/7 (Diesel Vehicles)
Description	GVM (t)	Designation						
Passenger Vehicles								
Cars	Not Applicable	MA	M1	Light Duty	*Euro 2*	*Euro 2 **	*Euro 3 **	*Euro 4*
Forward Control	Not Applicable	MB	M1	Light Duty	*Euro 2*	*Euro 2 **	*Euro 3 **	*Euro 4*
Off-road	Not Applicable	MC	M1	Light Duty	*Euro 2*	*Euro 2 **	*Euro 3 **	*Euro 4*
Buses								
Light	≤ 5	MD	M2 ≤ 3.5	Light Duty	*Euro 2*	*Euro 2 **	*Euro 3 **	*Euro 4*
			> 3.5 ≤ 5	Heavy Duty	*Euro 3**	*US 96*	*US 98*	*Euro 4*
Heavy	> 5	ME	M3	Heavy Duty	*Euro 3 or US 98 **	US 96	*US 98*	*Euro 4* or *US 2004 **
Goods Vehicles (Trucks)								
Light	≤ 3.5	NA	N1	Light Duty	*Euro 2*	*Euro 2 **	*Euro 3 **	*Euro 4*
Medium	> 3.5 ≤ 12	NB	N2	Heavy Duty	*Euro 3 or US 98 **	US 96	*US 98*	*Euro 4* or *US 2004 **
Heavy	> 12	NC	N3	Heavy Duty	*Euro 3 or US 98 **			*Euro 4* or *US 2004 **

1. The introduction of *Euro 2* and *Euro 3* standards will be via two new ADRs, one for light duty vehicles (adopting ECE R83) and one for heavy duty vehicles (adopting ECE R49 & US HDV standards). These new ADRs will replace ADR37/01 and ADR70/00.

2. A new smoke standard will also apply to all categories of diesel vehicles. The smoke standard will apply from 2002/3 and will adopt UN ECE R24/03 and allow the US 94 smoke standards as an alternative. This new ADR will replace ADR30/00.

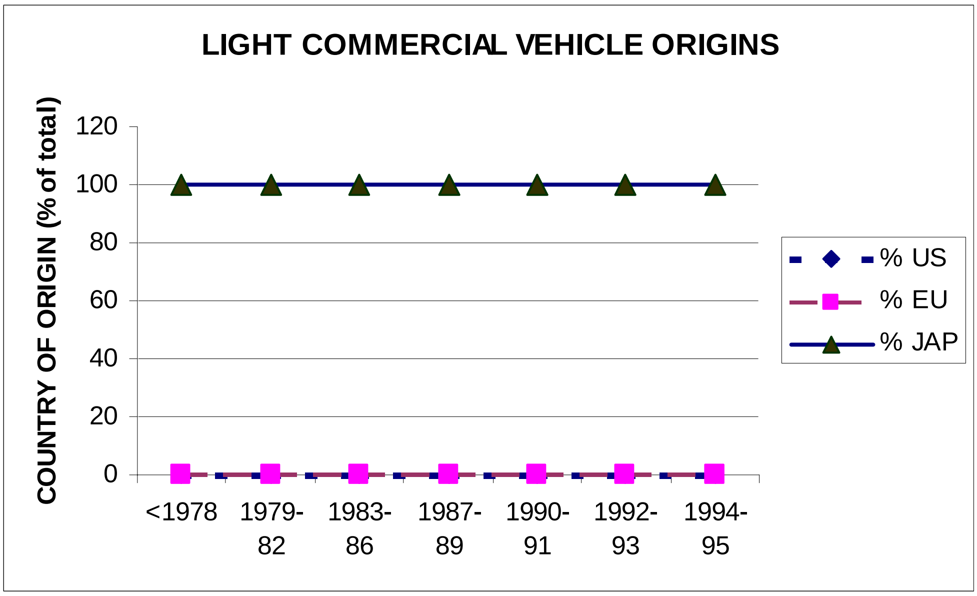
* Nominated standards also apply to vehicles fuelled with LPG or NG

2.11 COUNTRY OF ORIGIN OF AUSTRALIAN DIESEL VEHICLES

The previous section identified appreciable differences in the emission characteristics of diesel vehicles in Australia by vehicle age and by country of manufacture. Accordingly, it is necessary to determine the percentage of all diesel powered vehicle types by country of origin for all vehicle ages. The details of these interviews with manufacturers,ares given in **Appendix C** while graphical summaries of vehicle origins by vehicle type are given in **Figures 2.6 to 2.9**.

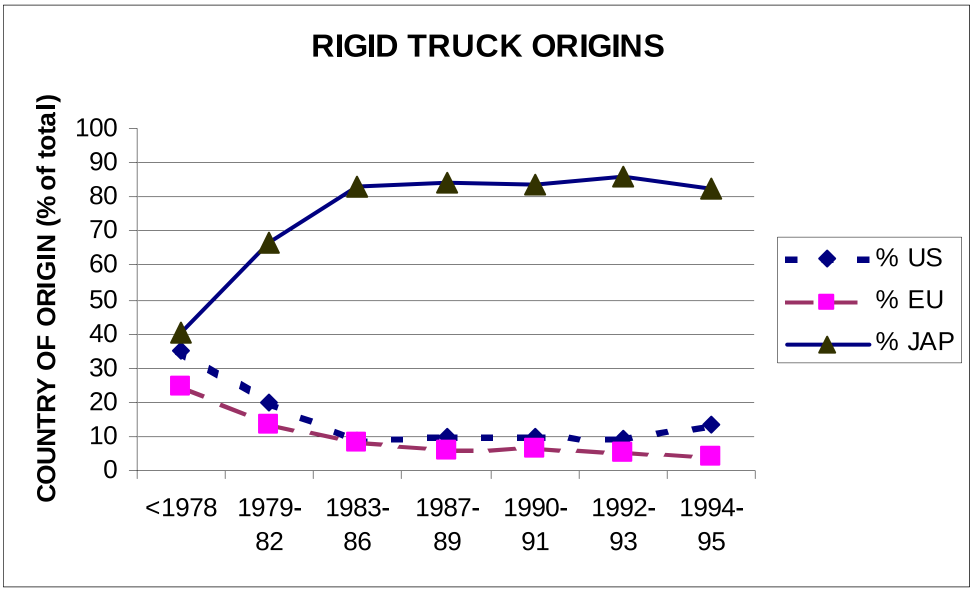
The dominance of Japanese manufacturers in light commercial vehicles, rigid trucks and buses during the 1980's is evident but an equilibrium seems to have been established in the 1990's. The US has maintained its dominance in articulated trucks but European manufacturers have achieved an appreciable share of the bus market.

Figure 2.6: Percentage of Total Diesel Light Commercials by Country of Origin and Year of Manufacture



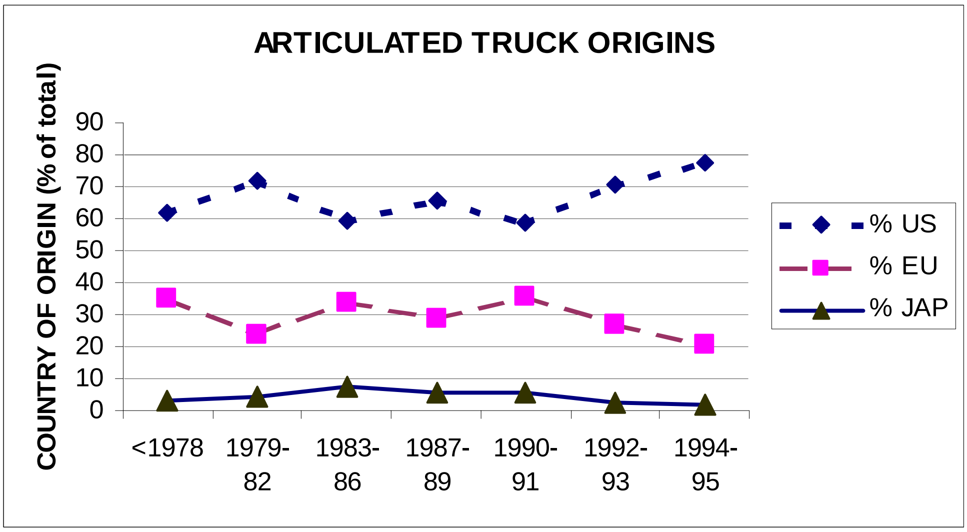
Source: Interviews with vehicle manufacturers (see Appendix B)
Note: Both the US and EU percentages of total LCV's are zero.

Figure 2.7: Percentage of Total Diesel Rigid Trucks by Country of Origin and Year of Manufacture



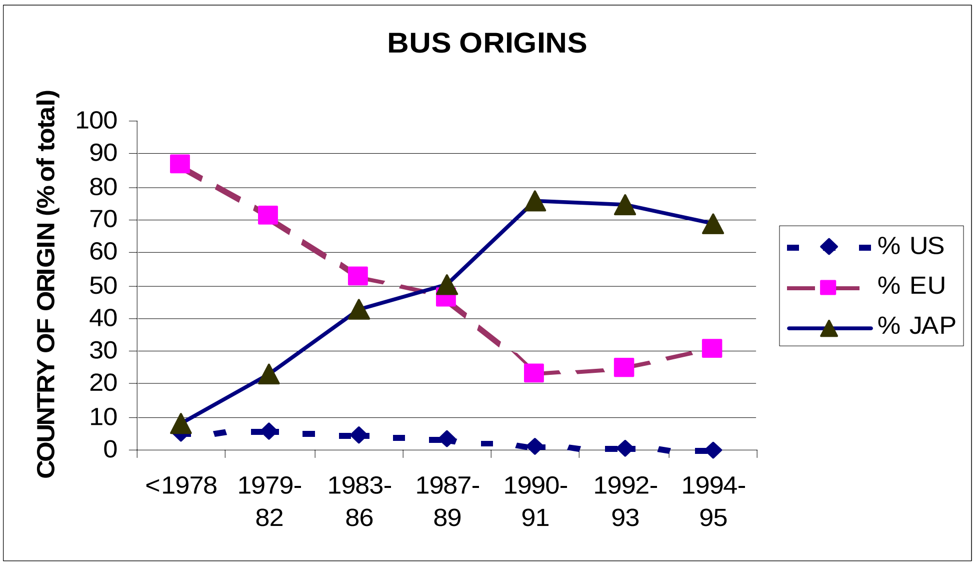
Source: Interviews with vehicle manufacturers (see Appendix B)

Figure 2.8: Percentage of Total Articulated Trucks by Country of Origin and Year of Manufacture



Source: Interviews with vehicle manufacturers (see Appendix B)

Figure 2.9: Percentage of Total Buses by Country of Origin and Year of Manufacture



Source: Interviews with vehicle manufacturers (see Appendix B)

2.12 EMISSION CHARACTERISTICS

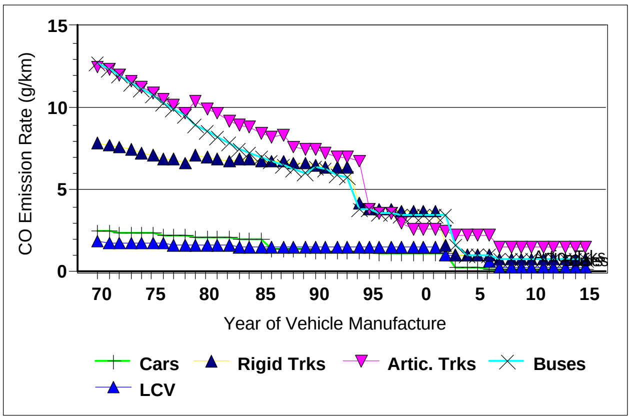
The diesel emission standards described in Section 2.10 are based on testing regimes that vary around the world. EPA NSW has analysed the effects of these standards on the emission rates of different vehicle types in different regions of the world and have combined these rates with the time lag experienced between the introduction of these standards in their country of origin and when vehicles with these standards arrive in Australia. A description of the assumptions used in deriving these emission rates is given in Appendix D[2].

These emission rates were extrapolated into the future based on the new fuel and emission standards that have recently been announced as part of the federal tax reform package. The emission rates from different regions were then combined with the proportion of vehicles imported from this region (as given in the previous section) to obtain a weighted average for each vehicle type and for every year of vehicle manufacture for vehicles operating in Australia.

Graphical summaries of these average emission rates from 1970 to 2015 are given below for the four major pollutants being analysed in this study, together with more detailed graphs of estimated and forecasted emissions since 1995. An examination of these figures indicates that the proposed standards will significantly reduce overall emissions as new vehicles are introduced into the vehicle fleet. This is particularly the case for rigid trucks that consume 40% of diesel fuel in the capital cities.

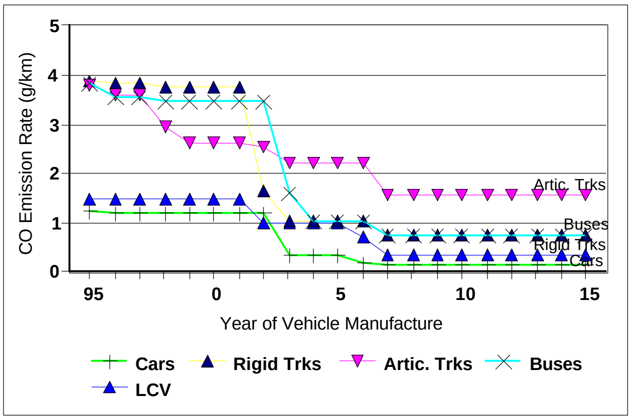
[2] The emission rates of the rigid truck category between 3.5 to 8 tonnes (GVM) in these tables were not used as it was assumed that the average GVM for Australian rigid trucks approximated 12 tonnes and that rigid truck emissions are related to this vehicle size. If the vehicle travel for all 2, 3 and 4 axle trucks with and without trailer as given in NRTC (1966a) is weighted by GCM then it can be calculated that the average GVM for the rigid truck category is 11.7 tonnes.

Figure 2.10: CO Emission Rates from 1970 (G/K)



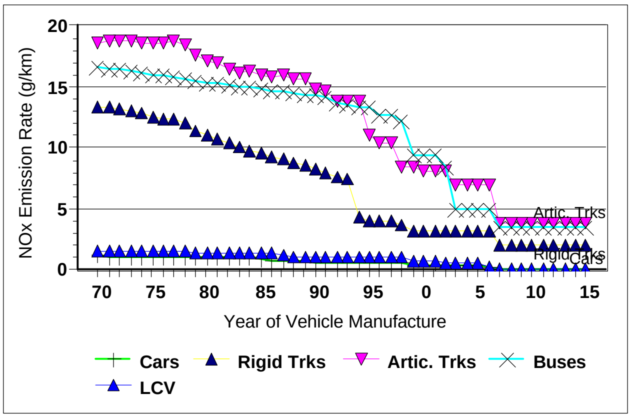
Source: NSW EPA (1999), personal communication

Figure 2.11: CO Emission Rates from 1995 (G/K)



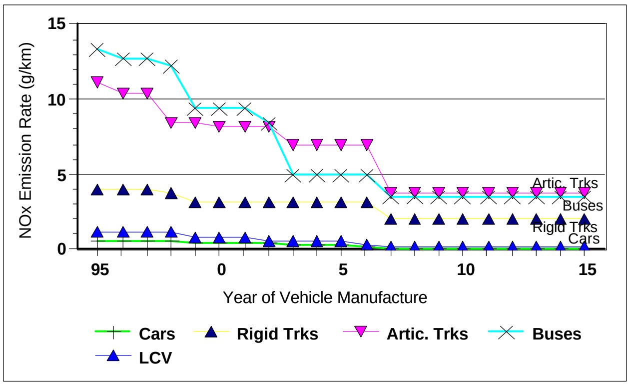
Source: NSW EPA (1999), personal communication

Figure 2.12: NOx Emission Rates from 1970 (G/K)



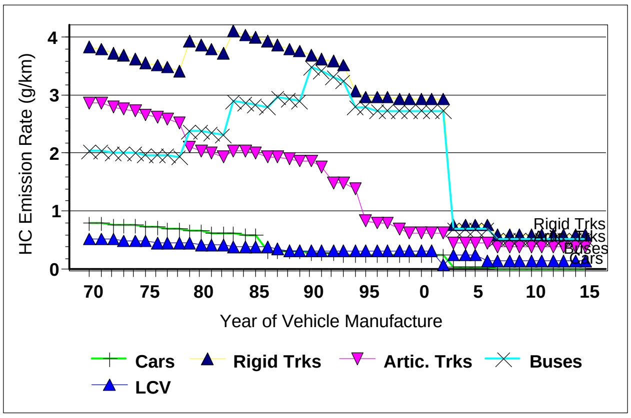
Source: NSW EPA (1999), personal communication

Figure 2.13: NOx Emission Rates from 1995 (G/K)



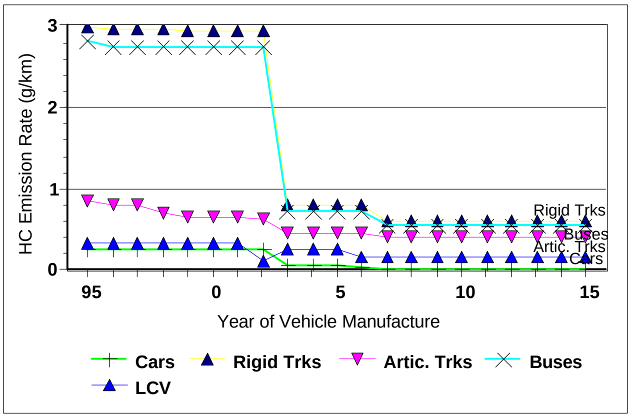
Source: NSW EPA (1999), personal communication

Figure 2.14: HC Emission Rates from 1970 (G/K)



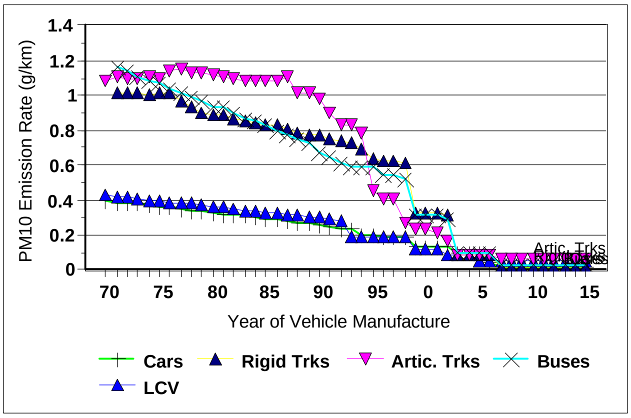
Source: NSW EPA (1999), personal communication

Figure 2.15: HC Emission Rates from 1995 (G/K)



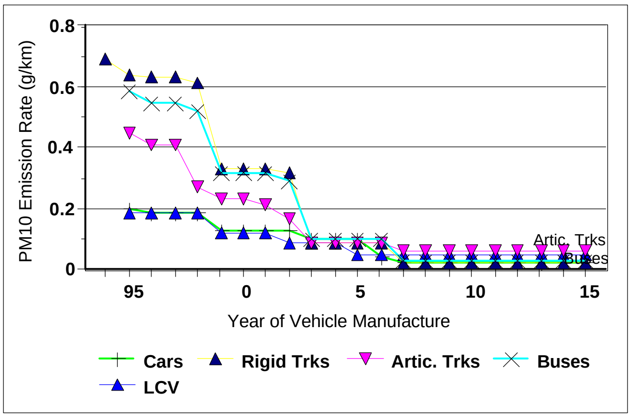
Source: NSW EPA (1999), personal communication

Figure 2.16: PM Emission Rates from 1970 (G/K)



Source: NSW EPA (1999), personal communication

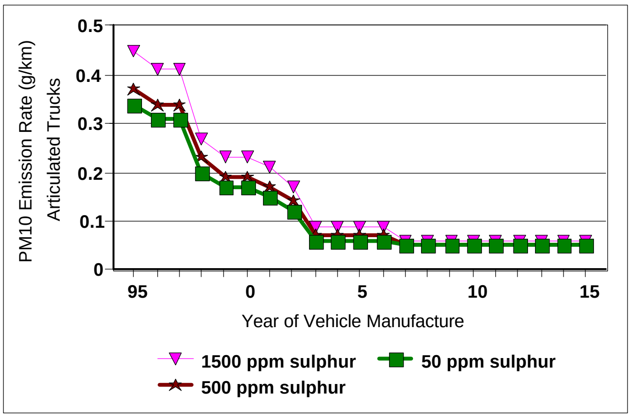
Figure 2.17: PM Emission Rates from 1995 (g/k)



Source: NSW EPA (1999), personal communication

A lower amount of sulfur in diesel fuel enables catalytic converters to be used, which in turn will lower CO, NOx and HC emissions. However EPA NSW considers that there is insufficient evidence to change emission levels of these pollutants with different sulfur levels in diesel fuel. This is not the case with particulates, though, as a reduction in sulfur reduces the secondary sulphate particles which are formed. Values for articulated trucks are given in the following figure and it is seen that the particulate levels in all of the older vehicles in the fleet also improve with lower sulfur fuel.

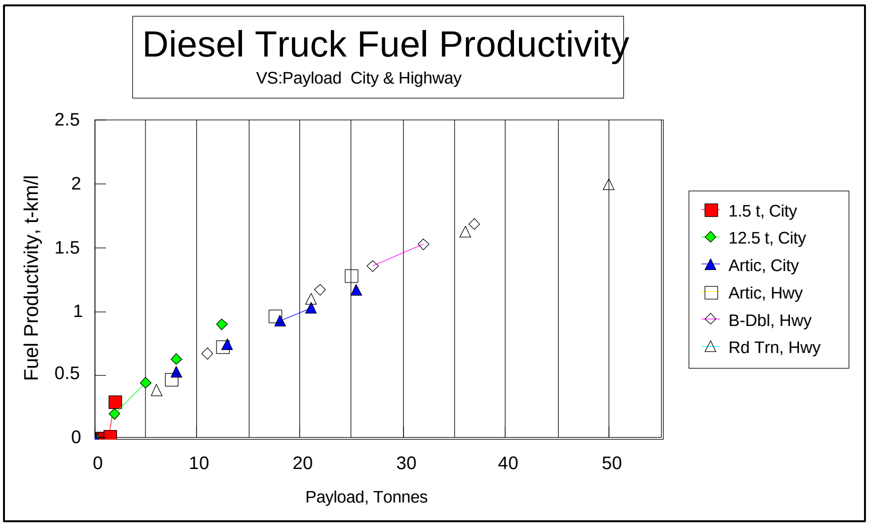
Figure 2.18: Effect of Diesel Fuel Standard on PM Emission Rates for Articulated Trucks (G/K)



Source: NSW EPA (1999), personal communication

It also should be noted that the overall amount of diesel emissions produced depends on the mix of freight vehicles that carry this freight in urban and rural areas. The larger vehicles are much more fuel efficient in delivering freight as shown in the following figure. This figure shows that more tonne-km are moved per litre of diesel fuel with larger vehicles.

Figure 2.19: Effect of Vehicle Size/ Payload on Diesel Fuel Productivity in Tonne-Km Per Litre of Fuel Used



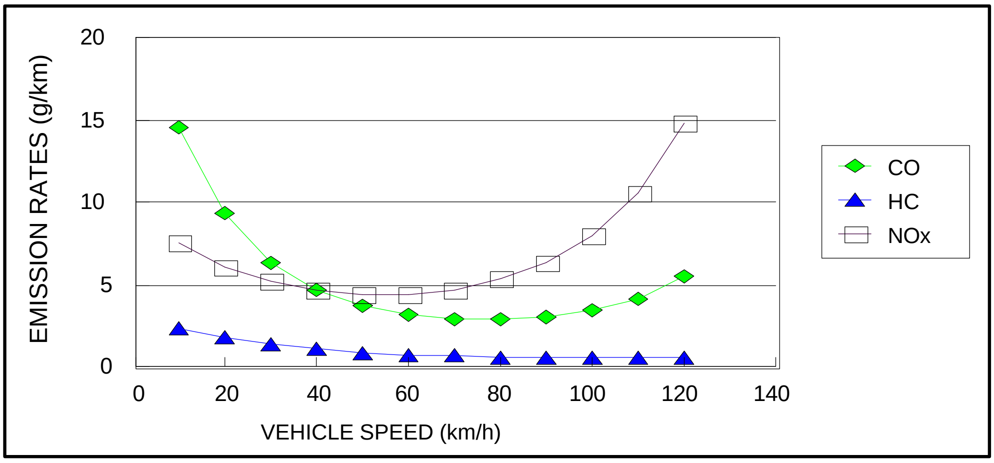
Source: Harry Close, 1998, personal communication

The emission productivity of freight vehicles would be even steeper than the above fuel productivity curve because the emissions per litre of fuel are much lower for articulated trucks than the smaller rigid trucks. Emission levels for rigid and articulated trucks are about the same but rigid trucks use 50 to 60% of the fuel of articulated trucks.

The test conditions for emission standards often do not reflect on road conditions. A major factor affecting the emission performance of on road vehicles is the nature and extent of stopping and starting cycles (which is often reflected in an average speed of the vehicle over a specified distance).

This is represented by the variation of heavy vehicle emissions with average vehicle speed as shown in **Figure 2.20**. The measurement of actual emission levels in tunnels (Sjodin et al 1998) shows the same trend with minimum emission levels for all pollutants at about 60 - 80 km/h and a rapid rise in the level of NOx and CO emissions as speeds increases. Further examination of the variation of emissions with speed will be made in Section 3.5.1 where the assumptions underlying the model are examined in more detail.

Figure 2.20: Variation of Heavy Vehicle Emission Levels with Average Vehicle Speed from Mobile 5.



Source: US EPA Mobile 5 emissions model

Quoted emission rates for various driving conditions and countries are given in **Tables 2.23 to 2.26** for CO, HC, NOx, and PM respectively. An examination of these tables indicates that driving conditions often have a greater effect on the magnitude of emissions than the varying test standards that have been adopted in each country. Emissions are seen to vary with the road type and travel conditions with three main road categories being given - urban, rural and motorway (see **Tables 2.23 – 2.26)**. These three road categories are also used to determine the growth of emissions in other emission analyses in Europe. Sometimes a congested road condition emission level is also used.

Early measurements of emissions in tunnels (almost 10 years ago) indicated that total emissions were being underestimated because of the small percentage of gross emitters in the vehicle fleet that were not being modelled correctly. Recent studies indicate a much closer correlation between actual and estimated emissions (Sjodin et al 1998), suggesting that the number of gross emitters is decreasing with the present, newer vehicle fleet or that the modelling of the gross emitters has been improved.

Table 2.23: CO Diesel Emission Rates (g/km)

	Cars	Light Trucks, LCV	Medium Trucks	Heavy Trucks	Buses
Mobile 5 - Base emission rates - Actual (advanced control to uncontrolled)	0.72 0.83-0.99	0.83 0.94 - 1.52		6.0 6.33 - 7.31	
BTCE TRUCKMOD		1.11	1.82	7.86	
EPA Victoria – Residential 1998 Arterial Freeway	1.97 1.11 0.90	5.35 3.46 3.23	13.16 8.50 7.95	13.16 8.50 7.95	
Europe – Metz 1992 Urban Rural Highway	1.30 0.60 0.20				
Europe – Samaras 1992 Urban Rural Motorway	1.0 0.5 0.4	2.4 0.8 0.6	18.8 7.3 4.2	18.8 7.3 4.2	
Europe – Sawer			3.41	5.37	
France – Roumegoux 95		1.2	3.1	3.2	
France – congested urban - Free flowing - Motorway - Motorway	 3.29 1.05 0.61				
London – Gore 1991					7.09
Netherlands – Veldt 1986 - Urban - Rural - Highway		3.5 1.5 0.9	10.0 4.0 1.5	16.0 5.0 2.0	
Greece – Pattas 1993	1.34		6.19		21.16 urban 4.95 rural
Chile – Escudero 1991					5.70
EPA NSW (1998) - Arterial - Highway/freeway - Commercial/arterial	1.167 1.167 1.257	1.505 1.290 1.809		8.739 7.475 10.634	

Sources:
Faiz et al, 1996.
EPA NSW (1998), pers. comm.

Table 2.24: HC Diesel Emission Rates (g/km)

	Cars	Light Trucks, LCV	Medium Trucks	Heavy Trucks	Buses
Mobile 5 – base emission rate -actual (advanced control to uncontrolled)	0.18 0.27 - 0.47	0.27 0.39 - 0.77	- 2.84	1.3 1.32 - 2.52	- 5.22
BTCE TRUCKMOD		0.53	0.99	2.78	
EPA Victoria 1998 Residential Arterial Freeway	0.78 0.50 0.47	1.29 0.83 0.78	2.40 1.55 1.45	2.40 1.55 1.45	
Europe – Metz 1992 Urban Rural Highway	0.10 0.10 0.10			5.78 2.58 2.27	
Europe – Samaras 1992 Urban Rural Motorway	0.31 0.11 0.11	0.51 0.21 0.11			
Europe – Sawer			0.61	1.0	
France – Roumegoux 95		0.9	0.8	1.1	
France – congested urban - Free flowing - Motorway - Motorway	1.04 0.29 0.09				
London – Gore 1991					1.19
Netherlands – Veldt 1986 - Urban - Rural - Highway		1.3 0.7 0.5	7.0 2.5 2.0	12.0 3.5 2.5	
Greece – Pattas 1993	1.81		2.68		5.57 – urban 2.15 – rural
Chile – Escudero 1991					1.40
EPA NSW (1998) - Arterial - Highway/freeway - Commercial/arterial	0.486 0.523 0.598	0.643 0.568 0.837		2.824 2.499 3.635	

Sources:
Faiz et al, 1996.
NSW EPA (1998), pers. comm.

Table 2.25: NOx Diesel Emission Rates (g/km)

	Cars	Light Trucks, LCV	Medium Trucks	Heavy Trucks	Buses
Mobile 5 - base emission rates - actual (advanced control to uncontrolled)	0.54 0.63-0.99	0.64 0.73-1.37		5.08 5.09-15.55	- 34.89
BTCE TRUCKMOD		1.18	3.10	15.29	
EPA Victoria 1998 Residential Arterial Freeway	1.07 1.07 1.07	1.35 1.35 1.35	8.77 8.77 8.77	8.77 8.77 8.77	
Europe – Metz 1992 Urban Rural Highway	0.90 0.79 0.97				
Europe – Samaras 1992 Urban Rural Motorway	0.7 - 1.0 0.4 – 0.7 0.5 – 0.9	1.7 1.2 1.3	8.7 7.4 6.0	16.2 14.8 13.5	
Europe – Sawer			6.58	16.9	
France – Roumegoux 95		1.6	12.0	6.7	
France – congested urban - Free flowing - Motorway - Motorway	 2.70 0.76 0.56				
London – Gore 1991					28.89
Netherlands – Veldt 1986 - Urban - Rural - Highway		1.3 1.3 1.4	10.0 10.0 13.0	20.0 20.0 25.0	
Greece – Pattas 1993	0.69		7.43		10.40 – urban 5.94 – rural
Chile – Escudero 1991					5.40
EPA NSW (1998) - Arterial - Highway / freeway - Commercial / arterial	1.004 1.004 1.004	1.158 1.158 1.158		15.246 15.246 15.246	

Sources:
Faiz et al, 1996.
NSW EPA (1998), pers. comm.

Table 2.26: Particulate Diesel Emission Rates (g/km)

	Cars	Light Trucks, LCV	Medium Trucks	Heavy Trucks	Buses
Mobile 5					
BTCE TRUCKMOD					
EPA Victoria Arterial/ Residential (1998) Freeway	0.190 0.10	0.26 0.14	2.09 1.15	2.09 1.15	
Europe – Metz 1992 Urban Rural Highway	0.30 0.29 0.37				
Europe – Samaras 1992 Urban Rural Motorway	0.36 0.13 0.17	0.33 0.13 0.16	0.95 0.82 1.67	1.60 1.40 1.25	
Europe – Sawer			0.55	0.61	
France – Roumegoux 95		0.9	0.5	1.4	
France – congested urban - free flowing - motorway - motorway	 0.68 0.29 0.25				
London – Gore 1991					1.69
Netherlands – Veldt 1986 - Urban - Rural - Highway		1.2 0.6 0.5	3.5 2.0 1.8	7.0 3.0 2.5	
Greece – Pattas 1993					
Chile – Escudero 1991					2.5
EPA NSW (1998) - Arterial - Highway/freeway - Commercial/arterial	0.129 0.071 0.259	0.376 0.207 0.752		0.432 0.238 0.865	

Sources:
Faiz et al, 1996.
NSW EPA (1998), pers. comm.

3. STRUCTURE OF THE FORECASTING MODELS

The objectives of the forecasting models are to:

(a) forecast vehicle emissions (CO, NOx, HC and PM) by vehicle type until the year 2015 by metropolitan area, State, Territory and nationally; and

(b) assess travel and emission outcomes resulting from alternative vehicle emission standards and policies.

The modelling framework incorporates four inter-connected spreadsheet models. The first is a NATIONAL TRAVEL DEMAND FORECAST MODEL that forecasts overall vehicle numbers and travel needed to meet the estimated private motorist, service industry and freight industry demand in Australia for road transport until the year 2015. The second is a STATE AND METROPOLITAN DEMAND FORECAST MODEL that allocates overall travel to the States, Territories and metropolitan areas in each State and Territory. The third model, titled a DISTRIBUTION OF TRAVEL MODEL, distributes this regional travel by vehicle age for each vehicle type. The fourth is an EMISSIONS FORECAST MODEL that estimates the emissions by road type in metropolitan areas as well as by State and Territory.

This section of the report summarises the methodology used to forecast vehicle travel demand and emissions by vehicle type, age, State and metropolitan area.

3.1 NATIONAL TRAVEL DEMAND

The NATIONAL TRAVEL DEMAND FORECAST MODEL utilises some of the relationships in the BTCE TRUCKMOD model as supplied by the Bureau of Transport Economics (BTCE 1996a). Our national travel demand model firstly describes the basic input assumptions and then estimates total Australian freight demand, light commercial travel and private travel for all years up to 2015. An estimate of the number of vehicles needed to fulfil this travel demand in Australia for five major vehicle types (cars, light commercial vehicles, rigid / other trucks, articulated trucks, buses) is also calculated. A schematic outline of the travel forecast model is given in **Flow Chart 1** following.

The primary purpose of the first model is to determine the total road freight demand and then distribute the freight task by vehicle type. The model includes assumptions of likely payloads, average distance travelled per year, the split of freight between vehicle types and adjustments to the BTCE assumptions on freight demand (BTCE (1996a) and BTCE (1996b)). The data items in the model are listed in **Table 3.1** and are followed by a more detailed description of the data elements and assumptions.

Flow Chart 1: National Travel Demand

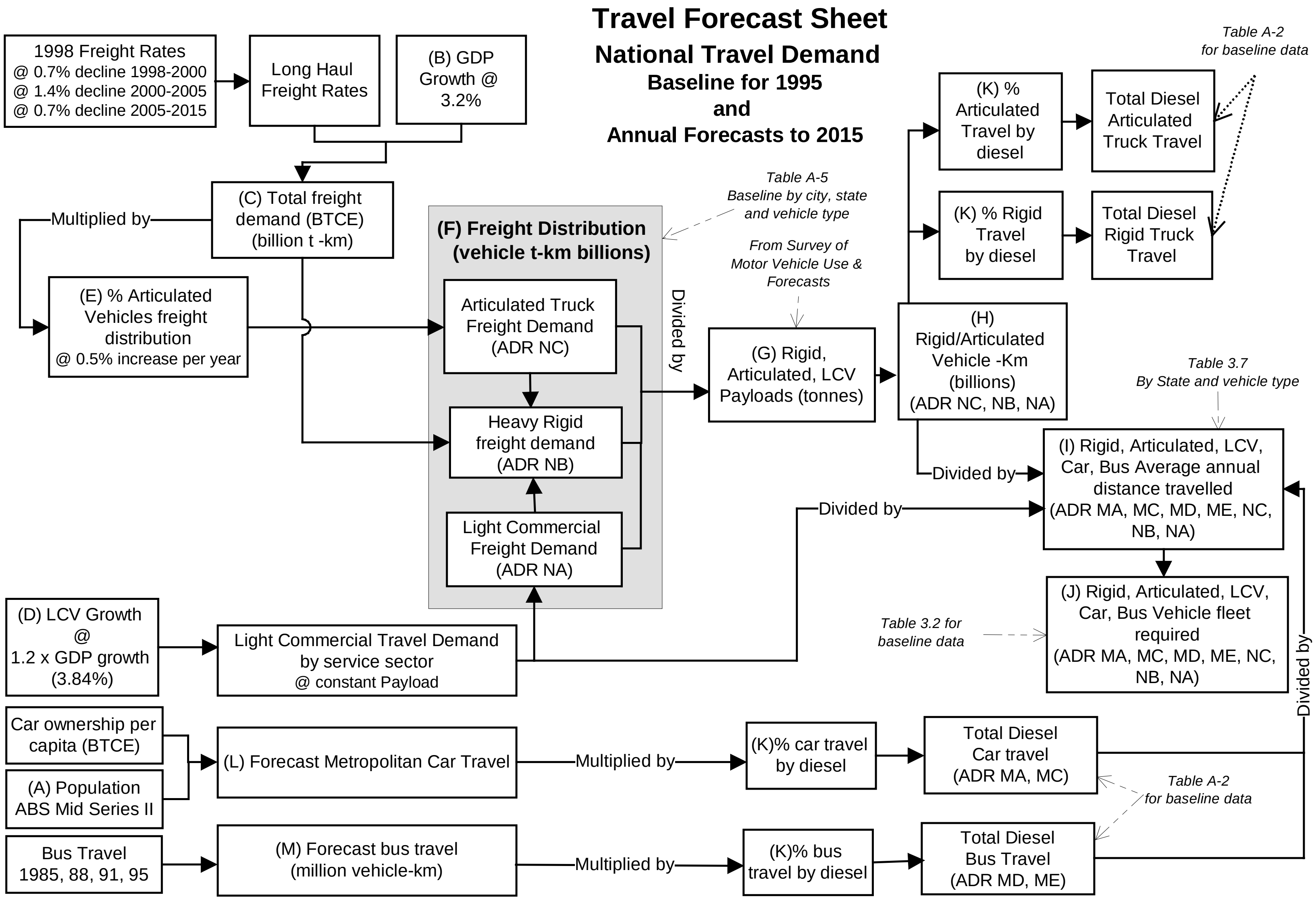


Table 3.1: Data Elements in the National Travel Demand Forecast Spreasheet

A. Population Projections
Australia
NSW
VIC
OLD
WA
SA
TAS
NT
ACT

B. Total Road Freight Projections
- GDP (million 89/90 dollars)
- long haul road freight rate (current $/tonne)
- CPI
- real long haul road freight rate (1990 $/tonne)
- total Australian road freight projections (billion t-km)
- BTCE road freight projections (billion t-km) – as a comparison only

C. Light Commercial Vehicle Freight Carried
- travel (billion veh-km)
- LCV Payload (tonnes)
- LCV billion tonne - km (vehicle km* payload)

D. Rigid Truck/ Articulated Truck Freight Distribution
- LCV (from C above)
- Rigid Trucks (total freight less LCV and artic. trucks)
- Artic. Trucks

E. Rigid Truck/ Articulated Truck Freight Distribution (billion t-km)
- LCV (from C above)
- Rigid Trucks
- Artic. Trucks

F. Payloads
- Rigid Trucks
- Articulated Trucks

G. Vehicle - km (billion)
- Cars (see J below)
- LCV (from C above)
- Rigid Trucks (freight carried / payload)
- Articulated Trucks (" ")
- Buses
- Other Trucks

H. Average Annual Distance Travelled (thousand km) – assumed for
- Cars
- LCV
- Rigid Trucks
- Articulated Trucks
- Buses

I. Vehicle Fleet (thousands)
- Car nos (thousands) (cars/person * population)
- LCV (vehicle km / annual distance travelled)
- Rigid Trucks (' ')
- Articulated Trucks (' ")
- Buses (' ")
- Cars/person (BTCE method)

J. Car Travel
- Annual Car Travel (thousand km)
- Car Travel (billion vehicle-km)

K. Diesel Travel (billion vehicle-km)
- Cars
- LCV
- Rigid Trucks
- Articulated Trucks
- Buses

L. Percentage Diesel to Total Travel
- Cars
- LCV
- Rigid Trucks
- Articulated Trucks
- Buses

A. Population: ABS middle Series II forecasts for Australia and all States (ABS Cat. No 3222.0) were used for projections after 1997. Population forecasts are used to estimate private car travel demand in each geographical area.

B1. GDP: Actual values in 1989/90 dollars are given by BTCE in TRUCKMOD until 1993. Actual values were extended until 1997 (1998 Commonwealth Year Book) and projections from 1998 onwards were made using the same growth rate as used by BTCE in TRUCKMOD (3.2% per annum). These GDP values are used to estimate total freight demand.

B2. Long Haul Freight Rates: These rates are also used to forecast total freight demand. Actual freight rates and the Consumer Price Indices (CPI) until 1993 were given by BTCE in Report 88 (BTCE 1995, Table VIII.8), enabling an assessment of real long haul freight rates to be made. Actual and real freight rates were updated to 1998 using TransEco and CPI data. Real freight rates were assumed to decline by 0.7% per year between 1998 and the year 2000, and also between 2005 and 2015, as per the BTCE assumption. Tsolakis, Murphy and Cox (1998) modelled the government's tax reform package and found that it would cause a decline in road freight rates of 7%. This decline in rates was assumed to occur between the years 2000 and 2005 after the introduction of the tax reform package, i.e. a rate of 1.4% per year over this 5 year period.

B3. Total Estimated Road Freight: The following formula was used in the TRUCKMOD projections of total road freight (BTCE 1995);

$$\ln(TOTFRT) = -4.46 + 1.058 * \ln(RGDP) - 0.923 * \ln(RROADLH)$$

Where

TOTFRT = total Australian road freight in million tonne-km

RGDP = GDP (E) measured at constant 1989/90 prices

RROADLH = real road freight rate

This correlation was based on data from 1966 to 1993. Using data from **1983 to 1995** the annual road freight task can be described by:

$$\ln(TOTFRT) = -16.443 + 1.573 * \ln(RGDP) + 0.166 * \ln(RROADLH)$$

Adjusted R squared = 0.976

DW Test = 1.18079

Estimation: Ordinary least squares

This formula gives a higher estimate of forecast road freight than the BTCE equation and shows that GDP has been more important in recent years (coefficient of 1.573 compared to 1.058) while the impact of the road freight rate is now minimal (coefficient of +0.166 compared to –0.923). A further correlation for the last 20 years **(1975 to 1995**) gave the following road freight model.

$$\ln(TOTFRT) = -8.096 + 1.276 * \ln(RGDP) - 0.748 * \ln(RROADLH)$$

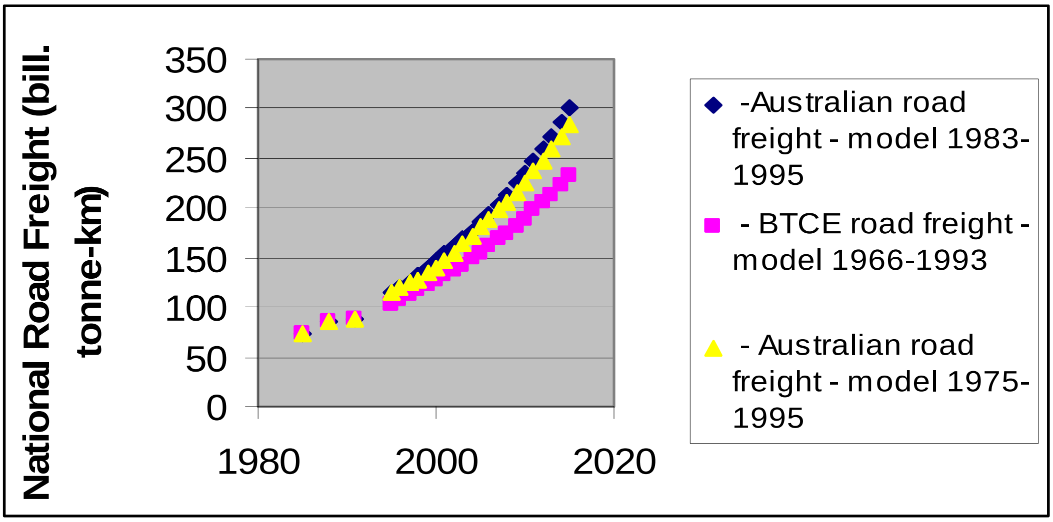
Adjusted R squared = 0.991

DW Test = 0.768

Estimation: Ordinary least squares

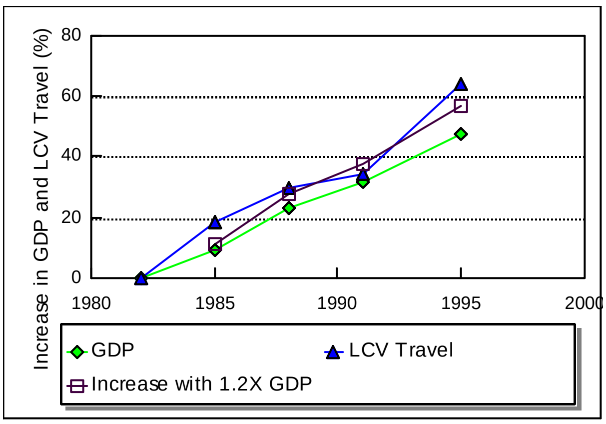
As would be expected the analysis for the twenty year period between 1975 and 1995 period gives coefficients which are intermediate between the 1966 to 1993 period and the 1983 to 1995 period. The differences in national road freight forecasts arising from the above correlations are given in **Figure 3.1** below. It is evident that both new models give higher national freight forecasts than the original BTCE model. As the difference in the forecasts between the two new models is minimal, the relationship developed between 1975 and 1995, which gives the same negative coefficient for the freight rate as the BTCE relationship, has been retained.

Figure 3.1: National Road Freight Demand Forecasts with Different Models



C. Light Commercial Travel and Freight Carried: LCV travel is influenced more by the demands of the service sector of the economy than by general freight demand. The following graph indicates that LCV travel has exceeded GDP growth by 20 per cent since 1982 suggesting that the services sector is growing at a faster rate than the overall national economy.

Figure 3.2: Increase in Light Commercial vehicle Travel with Economic Growth



Source: ABS

It is presumed that LCV travel will continue to increase at an annual rate of 1.2 times the forecast average growth in national GDP of 3.2 per cent, that is at 3.84 per cent per annum. This rate is lower than that evidenced in the 1990's but higher than the average growth in LCV travel, of 3.3 per cent per annum between 1985 and 1995.

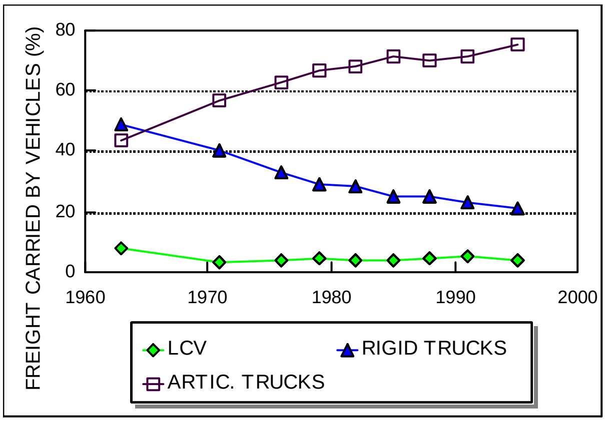
The freight task (tonne kilometres) undertaken by LCV's in the forecast period is the product of the LCV distance travelled and the average payload of the vehicle. The LCV payload is assumed to remain at the same level as determined in the 1995 Survey of Motor Vehicle Use (SMVU) by the ABS as:

(a) LCV's are used mainly in the services sector where there is no productivity gain from increased payloads in these vehicles; and

(b) there has been no change in payload over the last 10 years

D. Distribution of Total Road Freight (%): Figure 3.3 illustrates the distribution of freight shares for the commercial vehicles. The figure shows that articulated trucks have consistently increased their share by about 0.5 per annum per annum since 1980 and that this has been at the expense of rigid trucks.

Figure 3.3: Historical Percentage Distribution of Freight Carried by Vehicle Type



Source: ABS Surveys of Motor Vehicle Use

The trend to a greater freight share for articulated trucks is expected to continue with the gradual increase in the number of B Doubles and the anticipated increase in mass vehicle limits. At present, the percentage of articulated truck travel in Australian urban areas is low (23%) compared to that in US metropolitan areas (over 60%). US statistics (FHWA 1998) indicate that about 85% of all road freight in the US is moved by articulated trucks and that this share would be expected in Australia by 2015 if the freight share of articulated trucks continues to increase at 0.5 per cent per annum. It is assumed that the articulated freight share will increase by 0.5 per cent per annum up to the year 2015.
The percentage of freight carried by rigid trucks is derived as the balance of the proportion of freight carried by articulated trucks and the proportion of freight carried by LCV's.

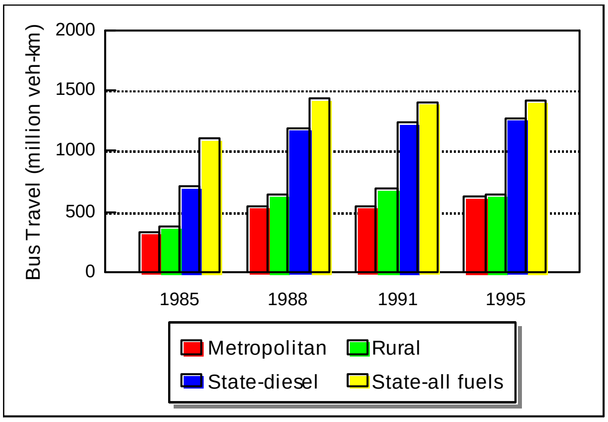
E. Distribution of Total Road Freight (billion tonne-km): The freight task by each commercial vehicle type is given as the total freight forecast multiplied by the percentage of freight carried by LCVs, rigid trucks and articulated trucks.

F. Payloads: Payloads on rigid and articulated trucks have been increasing at about 2.5 per cent per annum and 2.0 per cent per annum respectively. A 2.0 per cent annual increase in average payload for both rigid and articulated trucks has been assumed, particularly given the trend toward mass limit increases and advanced logistic systems that should facilitate more backloading.

G. Vehicle - Km Travelled : The distance travelled by the rigid and articulated truck fleets is estimated from their freight demand and average payload. The distance travelled by the LCV fleet has been derived in accordance with C above while car travel is estimated from the BTCE formula for cars/person (calculated in J below) and the average annual distance travelled by cars (as given in H below).

Figure 3.4 indicates relatively stable overall bus travel since 1988 despite diesel buses achieving a greater proportion of overall bus travel (increasing from 64% in 1985 to 89% in 1995). However, the proportion of travel by diesel bus has not significantly altered since 1991.

Figure 3.4: National Bus Travel by Area of Operation for Diesel Powered and All Vehicles



Source: ACG

The trend is towards a greater share of intercity travel by air (BTCE 1998) at the expense of rail while public transport patronage on buses in the metropolitan areas has remained static since 1988 (**Figure 3.5)**. It is therefore assumed that bus travel will remain at the 1995 values during the forecast period.

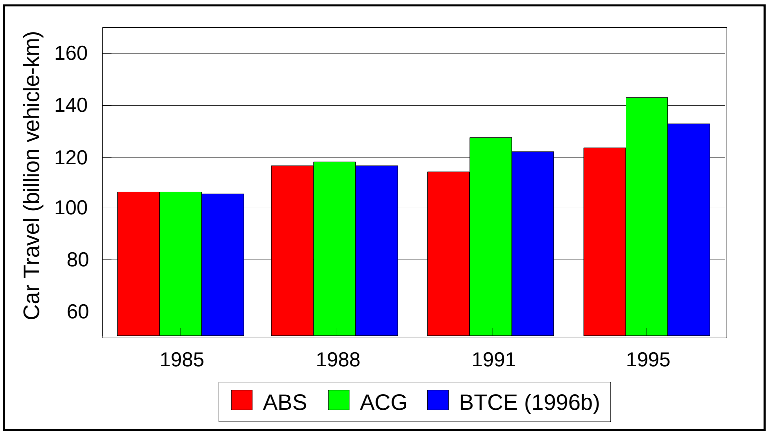
H. Average Distance Travelled Per Year: The annual distance travelled by LCV and rigid trucks has not changed substantially since 1985. Accordingly, it is assumed that the annual distance travelled by these vehicle types in 1995 will be maintained during the forecast period. The BTCE have also assumed no increase in annual distance travelled by articulated trucks despite the distance travelled increasing at an average 2,000 km per year for the last 20 years and an average 1,600 km per year for the last 10 years. It is assumed that the annual distance travelled by articulated trucks will increase by 1,600 km per year until 2005 and 1,000 km per year between 2005 and 2015.

The average distance travelled by cars is assumed to remain constant after 1995. This will be discussed in more detail in J below.

I. Vehicle Fleet Required: The number of vehicles required to undertake the estimated vehicle – km of travel is derived by dividing the forecast distance by the average annual distance travelled per year (for each vehicle type).

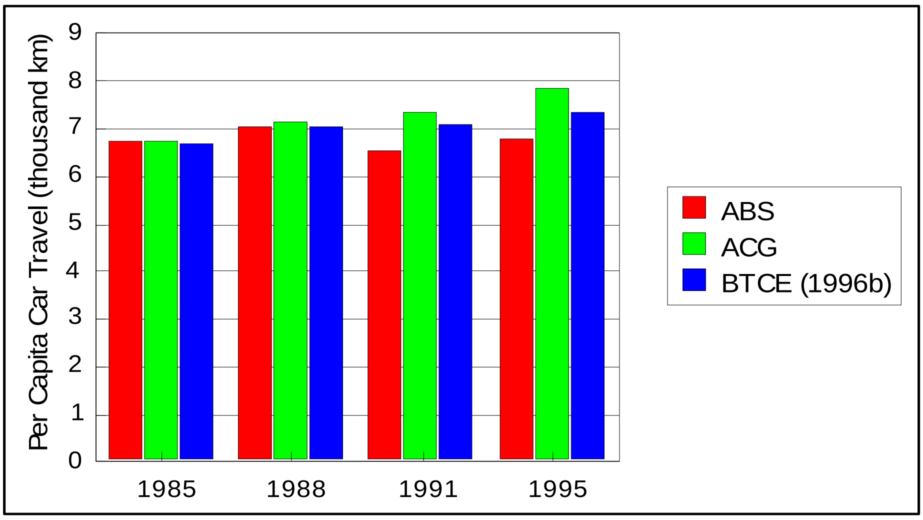
J. Car Travel: The ABS estimate of the total fuel used by passenger vehicles does not correspond with recorded petrol sales (ACG 1997). Adjustments by ACG indicate an increasing gap between total car travel by ABS and ACG **(Figure 3.5)** with the BTCE (1996b) results, being somewhere in between (the BTCE analysis is based upon the 1991 SMVU and does not reflect the outcome of the 1995 SMVU). This leads to static per capita passenger car travel from the ABS figures compared to a 1 per cent increase in per capita travel per year from the ACG figures **(Figure 3.6)**.

Figure 3.5: Differing Estimates of National Car Travel by ABS, ACG and BTCE



Source: ACG

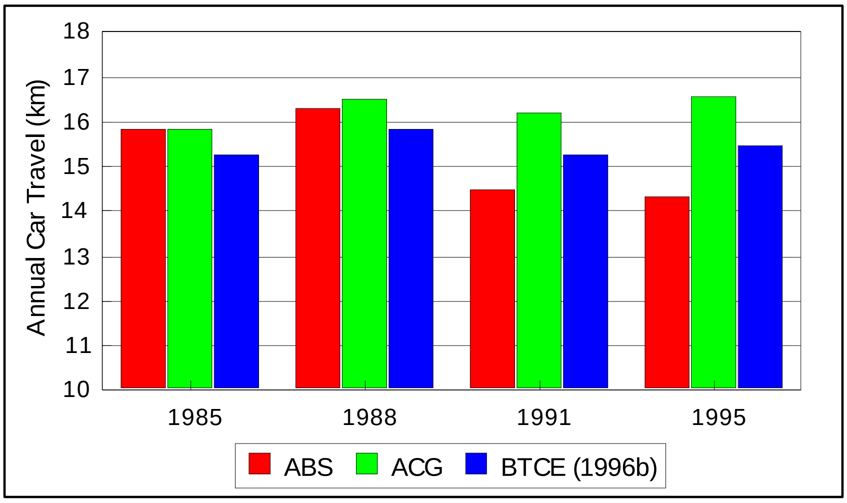
Figure 3.6: Differing Per Capita Car Travel



Source: ACG

The travel figures also show differences in the amount of annual travel undertaken by motor vehicles, with the ABS showing a significant decline in annual car travel in the 1991 and 1995 censi while both the ACG and the BTCE demonstrate more or less constant annual travel over the various surveys (see **Figure 3.7**).

Figure 3.7: Differing Annual Distance Travelled by Cars



Source: ACG

The BTCE in their CARMOD forecasting model agree with the ACG figures as they assume a constant 15,500 km annual travel into the future. The car population in CARMOD is derived using the following formula:

$$\text{Cars/thousand population} = k / (1 + a\, e^{-bt})$$

Where:

k = saturation level of car population (516 and 524 cars per thousand were assumed by BTCE),

t = time in years

a, b = constants
= 7.65 and 0.0896 for a saturation level of 516 cars per thousand
= 7.92 and 0.0890 for a saturation level of 524 cars per thousand

These equations were used with population forecasts to determine total estimates of the national car fleet for the forecast period. Forecasts of car travel were derived from estimates of the vehicle fleet and an assumed average annual travel of 16,000 kilometres per car.

K. Percentage of Diesel Travel: The above calculations reflect travel demand irrespective of fuel type. As the scope of the analyses in this study is confined to diesel vehicles the percentage of the total travel by diesel vehicles for each vehicle type needs to be identified.

The percentage of car travel contributed by diesel passenger vehicles was 1.6 per cent, 1.7 per cent, 2.6 per cent and 3.0 per cent of total passenger vehicle travel in 1985, 1988, 1991 and 1995, respectively. This equates to an increase of 0.14 per cent in travel by diesel powered passenger vehicles during the past ten years or 0.19 per cent during the past seven years.

The role of diesel vehicles in the Australian passenger vehicle fleet is much lower than in Europe (www.dieselnet.com update 21 November 1998) where the percentage of diesel cars has increased from 14 per cent in 1990 to 23 percent in 1998 (a growth of 1.1 per cent per annum). The role of diesel vehicles is projected to increase to 33 per cent in 2005 (future growth of 1.4 per cent per annum).

It is assumed that Australian diesel cars will increase their share of total car travel at their present rate of 0.15 per cent per year until 2015 when their market share will equate to 6.0 per cent. It should be noted though, that there are major advances in the technology of diesel engines that may contribute to significantly lower greenhouse gases and pollutants compared to petrol engines. If governments promote the use of diesel cars because of these advantages then the projection of the percentage of diesel car travel up to 2015 could be significantly underestimated.

The average values for the increase in the percentage of diesel travel for all vehicle types during the past ten years were used to extrapolate the percentage of diesel travel into the future **(Table 3.2)**.

Table 3.2: Annual Increase in the Percentage of Diesel Travel to Total Travel by Vehicle Type, 1985-1995

Vehicle Type	% Annual Increase in Diesel Travel
Cars	0.15
Light Commercial Vehicles	1.00
Rigid Trucks	1.00
Articulated Trucks	0.06
Buses	0.10

Source: Estimates of diesel travel in this report and spreadsheet model

3.2 STATE AND METROPOLITAN TRAVEL DEMAND

A separate model allocates the national travel demand by vehicle type to the various States, Territories and selected metropolitan areas. The data items in this model are listed in **Table 3.3**. A more detailed description of each data item and the assumptions follows the table. A schematic outline of the State and Metropolitan Travel Demand model is given in **Flow Chart 2**.

Table 3.3: Data Elements in the State and Metropolitan Travel Demand Forecast Model

A. Australian Travel Demand (billion vehicle-km) – from National Travel Demand Forecast spreadsheet
- Cars
- LCV
- Rigid Trucks
- Articulated Trucks
- Buses

B. Population Projections
Australia
NSW
VIC
QLD
WA
SA
TAS
NT
ACT
WA, NT & QLD – younger
NSW, VIC, SA, TAS, ACT – mature

C. GDP Projections
- GDP (million 89/90 dollars)
- GDP Mature States (mill. 89/90 dollars)
- GDP Younger States (mill. 89/90 dollars)
- Share mature States (%)
- Share younger States (%)

D1. Car Travel by State (billion vehicle-km)
- Cars per thousand people
- Annual Car Travel (thousand km)

Australia
NSW
VIC, etc

D2. Metropolitan Car Travel by State (billion vehicle-km) – from BTCE Working Paper 38
Australia
NSW
VIC, etc

D3. Non- metropolitan Car Travel by State (billion
Australia
NSW
VIC, etc

D4. State Travel by Diesel Powered Cars
Australia
NSW
VIC, etc

D5. Metropolitan Travel by Diesel Powered Cars
Australia
NSW
VIC, etc

D6. Non- metropolitan Travel by Diesel Powered Cars
Australia
NSW
VIC, etc

D7. Percentage of State Travel by Diesel Powered Cars
Australia
NSW
VIC, etc

D8. Percentage of Metropolitan Travel by Diesel Powered Cars
Australia
NSW
VIC, etc

D9. Percentage of Non-metropolitan Travel by
Australia
NSW
VIC, etc

Identical calculations are undertaken for all other road vehicles (LCVs, rigid / other trucks, articulated trucks and buses). Other Trucks have been aggregated with rigid trucks because they are such a small vehicle category.

Australian Travel Demand: The travel demand for each vehicle type is derived from the NATIONAL TRAVEL DEMAND FORECAST MODEL.

Population Projections: State population forecasts are given for the mid-range Series II projections by the ABS (Cat. No. 3222.0). The "younger" States and Territory of WA, QLD and NT have a much higher population growth than the "mature" States and Territory of NSW, VIC, SA, TAS and the ACT. The share of population of the younger states is estimated to increase from 28.6% in 1995 to 32.6% in 2015 (ABS).

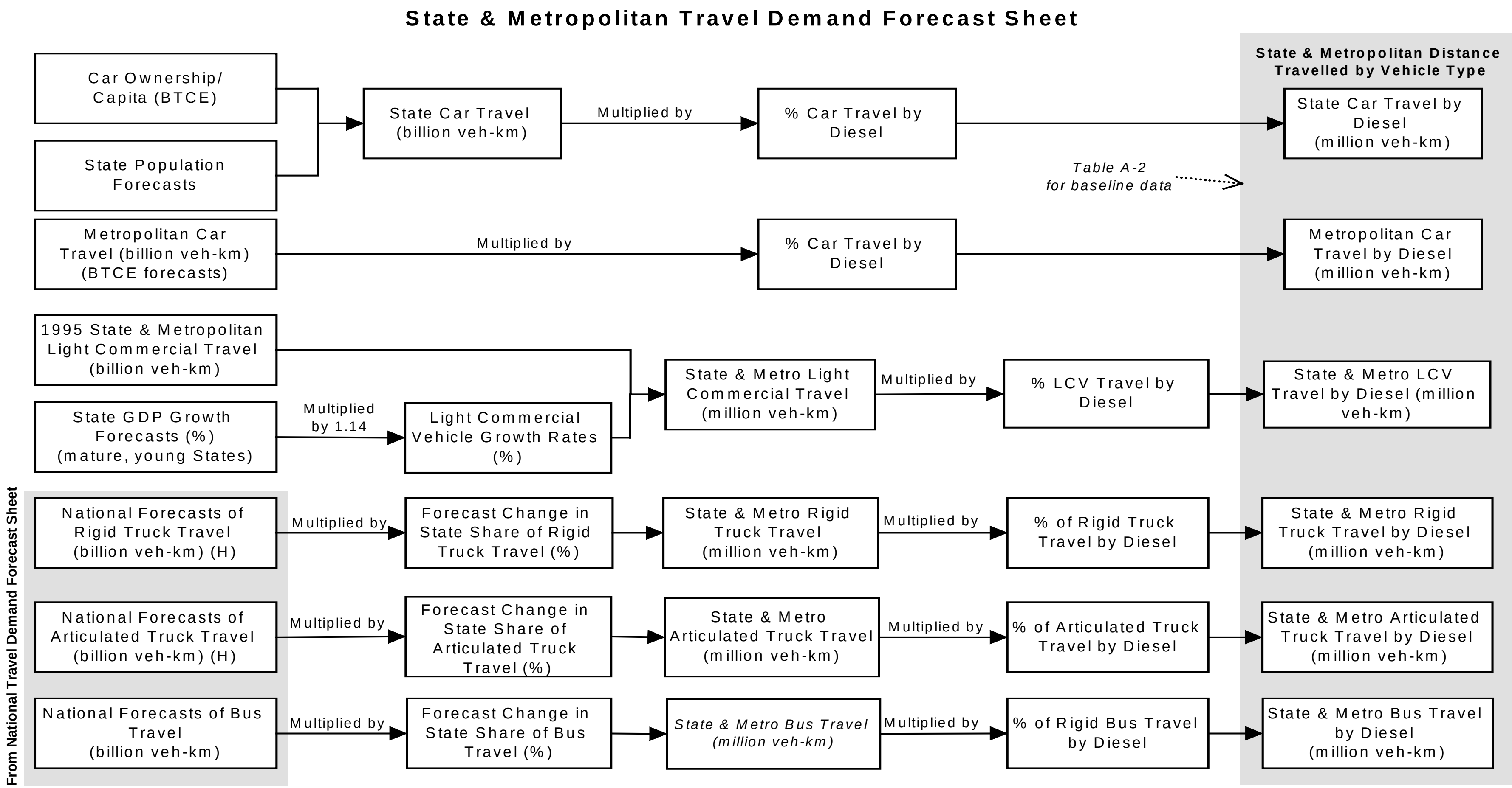
GDP Projections: Different GDP growth rates will be used for the more mature States (NSW, VIC, SA, TAS) and the faster growing younger States (WA, NT and QLD). Population and energy projections indicate that the market share of the younger States will increase (**Table 3.4)**. It is assumed that the younger States will achieve a 35 per cent increase in GDP by 2015.

Table 3.4: Percentage Shares for Younger States

	1995 Market Share (%) (WA, NT & QLD)	2015 Forecast Market Share (%)
Population	28.6	32.6
Energy	27	37
GDP	28.4	35 (assumed)

Source: ABS Cat. No. 3222.0 (1998) and Endersbee (1998).

Flow Chart 2: State and Metropolitan Travel Demand Forecast Sheet



In order to achieve an overall Australian GDP annual growth rate of 3.2 per cent (BTCE 1996a) and a GDP market share of 35 per cent for the younger States in 2015 (compared to 28.4 per cent in 1995), a 2.75 per cent per annum growth in GDP for the mature States and a 4.3 per cent per annum growth in GDP for the younger States has been assumed.

D1. Car Travel by State: The forecast car travel in each State is assumed to be a function of the existing car travel in the State, the forecast population growth in each State and the declining rate of increase in car ownership/capita. Accordingly, car travel will grow faster in the younger States primarily as a result of greater population growth. An approximate method was devised to apply the Australian increase in cars/thousand people to each State rather than deriving separate statewide correlations.

The total from all States by this method agrees well in the first few years but the State with the largest travel (NSW) has a much lower existing number of cars/thousand people and should therefore proceed along the steeper portion of the car ownership logistic S curve. However, it is assumed that the car ownership proceeds along the higher and flatter section of the Australian curve. As a result, the sum of all State travel in the later years of the forecast period is lower than that calculated for Australia as a whole. These differences in State car travel forecasts in general and diesel car travel in particular are not considered significant because of the small contribution of diesel cars to overall diesel emissions.

D2. Metropolitan Car Travel by State: BTCE (1998) have recently developed a model for passenger car travel forecasts in each metropolitan city until the year 2011. These forecasts have been adopted and extrapolated from the year 2011 to the year 2015.

D3. Non Metropolitan Car Travel by State: The difference between the State car travel forecasts in D1 above and the metropolitan travel forecasts in D2 is the non metropolitan car travel.

D4. State Travel by Diesel Powered Cars: Total travel by diesel powered vehicles by state/territory was derived by multiplying the total travel undertaken by all cars by the percentage of total travel by diesel powered cars. The percentage of car diesel travel in the forecast period is assumed to increase by 0.15 per cent per annum from the 1995 values in all states/territories (discussed in K and as calculated in D7 below).

D5. Metropolitan Travel by Diesel Powered Cars: Diesel car travel in metropolitan areas was derived by multiplying the amount of metropolitan car travel by the forecast percentage of diesel powered vehicles. The forecast percentage of diesel vehicle travel in metropolitan areas is also assumed to increase by 0.15 per cent per annum.

D6. Non Metropolitan Travel by Diesel Powered Cars: This is the difference between state/territories and metropolitan diesel car travel.

D7. Percentage of State Travel by Diesel Powered Cars; These are the existing state/territories percentage of diesel car travel as at 1995, inflated by 0.15 per cent per annum.

D8. Percentage of Metropolitan Travel by Diesel Powered Cars; These are the existing metropolitan percentages as at 1995 inflated by 0.15 per cent per annum.

D9. Percentage of Non-metropolitan Travel by Diesel Powered Cars; This is derived as the non-metropolitan diesel car travel divided by the non-metropolitan total car travel.

E1. LCV Travel by State/Territory: Australian LCV travel has previously been assumed to vary with GDP. As GDP growth is assumed to be larger in the younger States, the share of LCV travel in these states would also be expected to be larger over time. However, the proportion of the existing LCV travel in the younger States in 1995 (36.7%) is higher in the younger States than the existing shares of population (29%), electricity (27%) and GDP (28.4%). To obtain a similar travel figure in 2015 to the Australian forecast using these higher LCV base figures and higher GDP growth figures in the younger States it is necessary to reduce travel from 1.2 * GDP growth for the Australian LCV travel growth to 1.14* State GDP growth in all State calculations.

E2. Metropolitan LCV Travel: Derived from the existing metropolitan LCV travel figures and escalated by 1.14 * GDP growth.

E4 – E9. LCV Diesel Travel Forecasts: The LCV State and Metropolitan diesel travel forecasts are similar to those adopted for car travel except that an increase of 1.0 per cent per annum in the percentage of diesel LCV travel to total LCV travel has been assumed for state, territory and metropolitan areas.

F1 – F9. Rigid/Other Truck Travel[3] by State: Historically, the percentage share of national rigid and other truck travel at State and metropolitan levels has not been constant. Rounded average percentage changes to the national share of state, territory and metropolitan **total** rigid truck and articulated truck travel between 1985 and 1995 are given in the table below. These historical changes have been used to estimate the change in state/territory shares of total national truck travel into the future.
The metropolitan share of **total** rigid truck travel as a percentage of total rigid truck travel has been increasing by 0.5 per cent per annum. This trend has been maintained in the forecasts.

Table 3.5: Annual Increase in State and Metropolitan Truck Travel Percentage Share, 1985-1995

	State Area		Metropolitan Area	
	Rigid Trucks	Artic Trucks	Rigid Trucks	Artic Trucks
NSW	-0.32	-1.00	-0.10	-0.35
VIC	0.07	0.37	-0.02	0.67
QLD	0.53	0.60	0.21	-0.04
WA	-0.13	0.07	0.02	0.05
SA	-0.09	-0.05	-0.09	-0.31
TAS	-0.07	0.01	-0.01	0.04
NT	-0.01	-0.02	0.00	-0.05
ACT	0.02	-0.02	0.01	-0.01

Source: Data in Interim Report 4.1 for this project

[3] The ABS category of other truck travel is quite small and this travel will be included in with rigid truck travel.

The amount of travel by **diesel** rigid / other trucks has been estimated from the total state / territory rigid / other truck travel by assuming that the percentage of diesel travel will continue to increase by 1.0 per cent per annum from existing state, territory and metropolitan percentage values until 100 per cent is attained. Travel by diesel powered rigid / other trucks in the state / territory and metropolitan regions is the product of total travel and the percentage of diesel travel in these areas, for each year. Travel by diesel powered rigid / other trucks in non metropolitan areas is estimated as the difference between state / territory and metropolitan travel.

G1-G9. Articulated Truck Travel by State: The above methodology for diesel rigid truck travel was adopted for articulated trucks with the exception that the percentage of State and metropolitan diesel articulated truck travel was assumed to grow by 0.06 per cent per annum.

The market share of total State articulated travel in NSW has decreased from 34.4 per cent of the national total in 1985 to 24.4 per cent in 1995, or –1.0 per cent per annum. Extrapolation of this same decline in national share for the next 20 years would leave NSW with only a 4% share of State articulated travel in the year 2015, which is unreasonable. The rate of change in State shares of articulated truck travel for NSW, Victoria and Queensland was presumed to halve to –0.5 per cent per anum, +0.2 per cent per anum and +0.3 per cent per anum, respectively.

The metropolitan share of articulated truck travel as a percentage of total articulated truck travel has been increasing at 0.2 per cent per annum. This trend was factored into the analyses.

H1- H9. Bus Travel by State: As there has been no discernible change in the share of state / territory and metropolitan bus travel in recent years, the forecast shares have been retained at 1995 levels. Further, overall bus travel in state / territory and metropolitan areas has been retained at existing levels because of no discernible trends in recent surveys (see **Figure 2.4**). An increase in the percentage of diesel powered bus travel by 0.1 per cent per annum until 100% is reached does increase the amount of diesel bus travel over the forecast period.

3.3 DISTRIBUTION OF VEHICLE TRAVEL

The STATE AND METROPOLITAN DEMAND MODEL is followed by a DISTRIBUTION OF VEHICLE TRAVEL MODEL for each vehicle type. This model estimates the annual distance travelled at each vehicle age (or year of manufacture) for each vehicle type. A schematic representation of the model is given in the following **Flow Chart 3**.

A distribution of vehicle travel over various vehicle ages is required because emissions are lower for newer vehicles. We also need to determine the new vehicles being added to the fleet (as well as the emission standards of these new vehicles).

One of the problems in this analysis is that additions to the vehicle fleet are quite dynamic. Thoresen and Wigan (1985) show that survival and scrappage rates over the period 1971 to 1982 in Australia vary quite dramatically in response to market forces. This was also shown to be the case in New Zealand (Bennett 1990).

Vehicle age influences two other variables besides emission rates. First, for each vehicle type, the percentage of the total vehicle fleet in any age group generally decreases with vehicle age due to scrappage. Second, the annual distance travelled by any particular vehicle also decreases with vehicle age.

The product of the percentage of vehicles and the distance travelled at each vehicle age gives the percentage of the total distance travelled in each vehicle age group for the vehicle type being examined. The percentage of total distance travelled in each age group for 1985, 1988, 1991 and 1995 by each vehicle type was found to be more constant than vehicle numbers. Accordingly, the distribution of the percentage of total distance travelled by age and vehicle type was derived (see **Table 3.6)** and applied to the forecast travel in the state/territory and metropolitan areas (as determined in the previous STATE AND METROPOLITAN TRAVEL DEMAND MODEL).

Flow Chart 3:

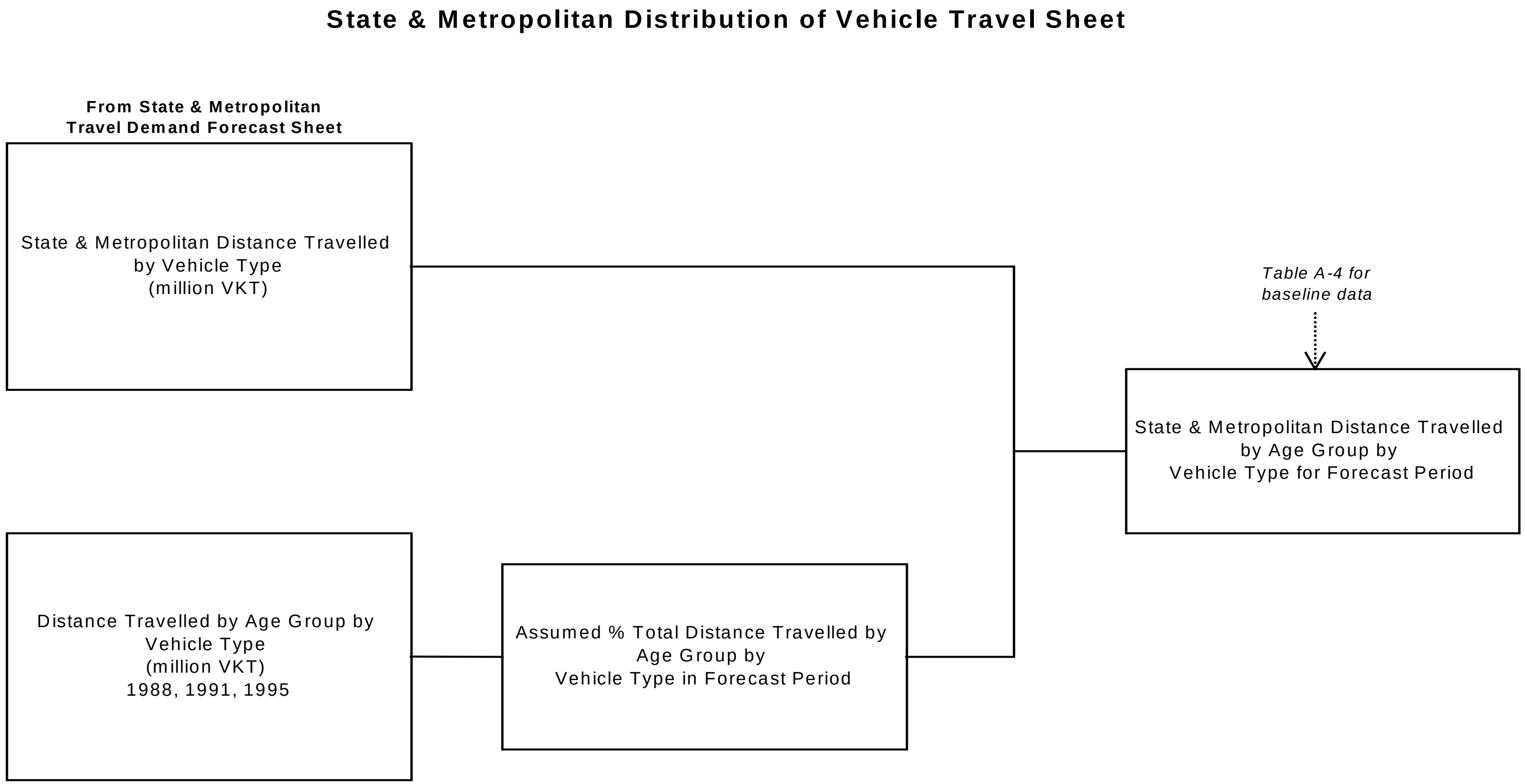

State & Metropolitan Distribution of Vehicle Travel Sheet
From State & Metropolitan
Travel Demand Forecast Sheet
State & Metropolitan Distance Travelled
by Vehicle Type
(million VKT)
Table A-4 for
baseline data
State & Metropolitan Distance Travelled
by Age Group by
Vehicle Type for Forecast Period
Distance Travelled by Age Group by
Vehicle Type
(million VKT)
1988, 1991, 1995
Assumed % Total Distance Travelled by
Age Group by
Vehicle Type in Forecast Period

Table 3.6: Percentage of Total Travel by Age Group for Different Vehicle Types

Age (Yrs)	Cars	LCV	Rigid Trucks	Artic Trucks	Buses	Comments
0	4.0	4.5	3.00	5.0	4.0	Travel in Year 0 is lower as some
1	8.5	9.5	4.50	10.0	8.5	vehicles are purchased during. the
2	8.5	9.0	5.50	10.0	8.5	year and do less travel
3	8.3	8.5	7.00	9.2	8.3	
4	7.8	8.0	7.00	8.6	7.8	
5	7.4	7.5	7.00	8.0	7.4	
6	6.9	7.0	7.00	7.4	6.9	
7	6.5	6.5	6.50	6.8	6.5	
8	6.0	6.0	6.40	6.2	6.0	
9	5.5	5.5	5.98	5.6	5.5	
10	5.1	5.0	5.56	5.0	5.1	
11	4.6	4.5	5.14	4.4	4.6	
12	4.2	4.0	4.72	3.8	4.2	
13	3.7	3.5	4.30	3.2	3.7	
14	3.2	3.0	3.88	2.6	3.2	
15	2.8	2.5	3.46	2.0	2.8	
16	2.3	2.0	3.04	1.4	2.3	
17	1.9	1.5	2.62	0.8	1.9	
18	1.4	1.0	2.20		1.4	
19	0.9	0.5	1.78		0.9	
20	0.5	0.3	1.36		0.5	
21		0.2	0.94			
22			0.52			
23			0.30			
24			0.20			
25			0.10			
>25						
Total	100.0	100.0	100.0	100.0	100.0	

Source: Interim Report 4.1 for this project.

The vehicle-km by vehicle age group for each year of the forecast period was derived from the total forecast travel in the various states/territories and metropolitan areas for each vehicle type and from the above travel distributions.

The data items used in this spreadsheet model are detailed in **Table 3.7.** A more detailed description of these items follows the table. The distribution of travel by vehicle age is calculated separately for metropolitan and non-metropolitan travel as the emission characteristics differ in each area. Total State emissions are estimated from the sum of these emissions.

Table 3.7: Data Elements in the Distribution of Vehicle Travel Spreadsheet

A. CAR TRAVEL- FROM PREVIOUS SPREADSHEETS

- Australian Car Travel (billion veh-km)
- Australian Car Numbers (thousands)
- Average Annual Utilisation (thousand km)
- Australian Diesel Car Travel (billion veh-km)
- NSW Metropolitan Diesel Car Travel (billion veh-km)
- NSW Non-metropolitan Diesel Car Travel (billion veh-km)
- VIC Metropolitan Diesel Car Travel (billion veh-km)
- VIC Non-metropolitan Diesel Car Travel (billion veh-km)
- QLD Metropolitan Diesel Car Travel (billion veh-km)
- QLD Non-metropolitan Diesel Car Travel (billion veh-km)
- WA Metropolitan Diesel Car Travel (billion veh-km)
- WA Non-metropolitan Diesel Car Travel (billion veh-km)
- SA Metropolitan Diesel Car Travel (billion veh-km)
- SA Non-metropolitan Diesel Car Travel (billion veh-km)
- TAS Metropolitan Diesel Car Travel (billion veh-km)
- TAS Non-metropolitan Diesel Car Travel (billion veh-km)
- NT Metropolitan Diesel Car Travel (billion veh-km)
- NT Non-metropolitan Diesel Car Travel (billion veh-km)
- ACT Metropolitan Diesel Car Travel (billion veh-km)
- ACT Non-metropolitan Diesel Car Travel (billion veh-km)

B1. NSW Metropolitan Diesel Car Travel (million veh-km)

Vehicle Age (yrs)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
>25
Totals

B2. NSW Non-metropolitan Diesel Car Travel (million veh-km)

Vehicle Age (yrs)
0
1 Etc
Totals

A. Car Travel Data: Annual diesel car travel data for Australia and the metropolitan and non-metropolitan areas in each state/territory are derived from the STATE AND METROPOLITAN DEMAND FORECAST MODEL.

B1. NSW Metropolitan Areas: The forecast annual travel in the NSW metropolitan area by vehicle age is calculated from the product of the forecast diesel car travel in the NSW metropolitan area and the percentage of total travel in each vehicle age group.

B2. NSW Non- metropolitan Areas: The forecast annual travel in the NSW non-metropolitan area by vehicle age is calculated from the product of the forecast diesel car travel in the non-metropolitan area of NSW and the percentage of total travel in each age group.

Diesel car travel in the metropolitan and non-metropolitan regions for the other states/territories is estimated as per NSW above. The same methodology is applied to LCV's, rigid/other trucks, articulated trucks and buses.

The distance travelled in each geographical area by vehicle type is applied in conjunction with the emission standards for various vehicle ages to determine total emissions. If a new emission standard is introduced in year 1 so that it applies to all vehicles in that year and new vehicle sales in subsequent years, then the distance travelled by vehicles with this standard in year 2 is the sum of the distances travelled by vehicles in the first two age groups with ages 0 and 1 years.

3.4 ESTIMATE OF UNCERTAINTY OF TRAVEL

Macro estimates of travel demand are based upon methodologies adopted by the BTCE (1995, 1998) except for LCV travel, which has been based on the growth of the services sector of the economy. These national demand forecasts have been distributed to the States and metropolitan areas according to:

- estimates of population and GDP growth;
- national trends in the distribution of freight to various vehicle types; and
- the increase in diesel travel as a percentage of total travel.

The estimates could be different from those built up completely from State level studies as individual State trends on the distribution of freight to various vehicle types and the increase in diesel travel as a percentage of total travel may be different from the national trends which have been assumed. However, the accuracy of ABS data often decreases as one proceeds to smaller State and areas of operations, particularly for individual vehicle types.

The uncertainties in estimates of travel demand are lower if the error is expressed in terms of total travel in any particular year. This is demonstrated in **Table 3.8** which gives the total national diesel travel forecasts by all vehicle types as at 2005 together with the percentage error in total travel for an assumed 50 per cent error in the forecast **increase** in diesel travel between 1995 and 2005.

Table 3.8: Estimates of Uncertainty for Total Diesel Travel with 50 Percent Error in Increase in Diesel Travel

Vehicle Type	1995 Travel (bill veh-km)	2005 Travel (bill veh-km)	Increase in Travel (bill veh-km)	% Increase 1995 - 2005	Error in Total Diesel Travel for 50% Error in Increase
Cars	4.23	6.83	2.60	61.5%	19.0%
Light Commercials	6.87	13.14	6.27	91.2%	23.9%
Rigid Trucks	5.87	6.58	0.71	12.1%	5.3%
Artic. Trucks	4.86	6.70	1.84	37.8%	13.7%
Buses	1.27	1.28	0.01	0.8%	3.9%

The largest anticipated increase in diesel travel is seen to be for light commercial vehicles followed by diesel cars. The growth in diesel travel is largely due to the assumed increase in the percentage of diesel vehicle travel to total travel for both vehicle types over the forecast period.

A 50 per cent error in the ten year forecast growth of diesel travel in each of these vehicle types results in errors of 5 to 20% in total diesel travel in the year 2005 and has the greatest effect on the fastest growing vehicle types of light commercials, cars and articulated trucks.

The greatest uncertainty in the diesel travel forecasts is likely to be experienced by cars and light commercial vehicles. Technological improvements in European diesel cars is expected to be significant in the next decade and may result in substantial market share growth for diesel cars in Europe. The estimate of 6 per cent diesel share of Australian car travel in the year 2015 may therefore be significantly underestimated if this diesel car technology is introduced into Australia. For LCVs, it is assumed that the current growth in the service sector will continue and that the need for LCVs to service this sector will be maintained.

Overall, the trends over the past ten years have been used as the basis to extrapolate future trends. These trends should be reviewed on an ongoing basis as new data becomes available.

3.5 VEHICLE EMISSIONS

Flow Chart 4 describing the VEHICLE EMISSIONS MODEL is given below. The assumptions associated with this model are outlined below.

3.5.1 MODEL ASSUMPTIONS

Assumption 1: Percentage Travel on Metropolitan Functional Road Types

The National Road Transport Commission (NRTC) estimated the distribution of traffic on arterial and local roads for each Australian city (NRTC, 1996). Arterial traffic was divided into roads carrying traffic above 20,000 AADT and less than 20,000 AADT. No estimate of freeway traffic was provided. The NRTC data is presented below together with the distance of freeways in all capital cities (Cox 1997). An estimate of the amount of freeway travel can be made by assuming an average daily traffic of 70,000 vehicles/day for 300 days on freeways in the major cities of Sydney and Melbourne and 50,000 vehicles/day in the other cities.

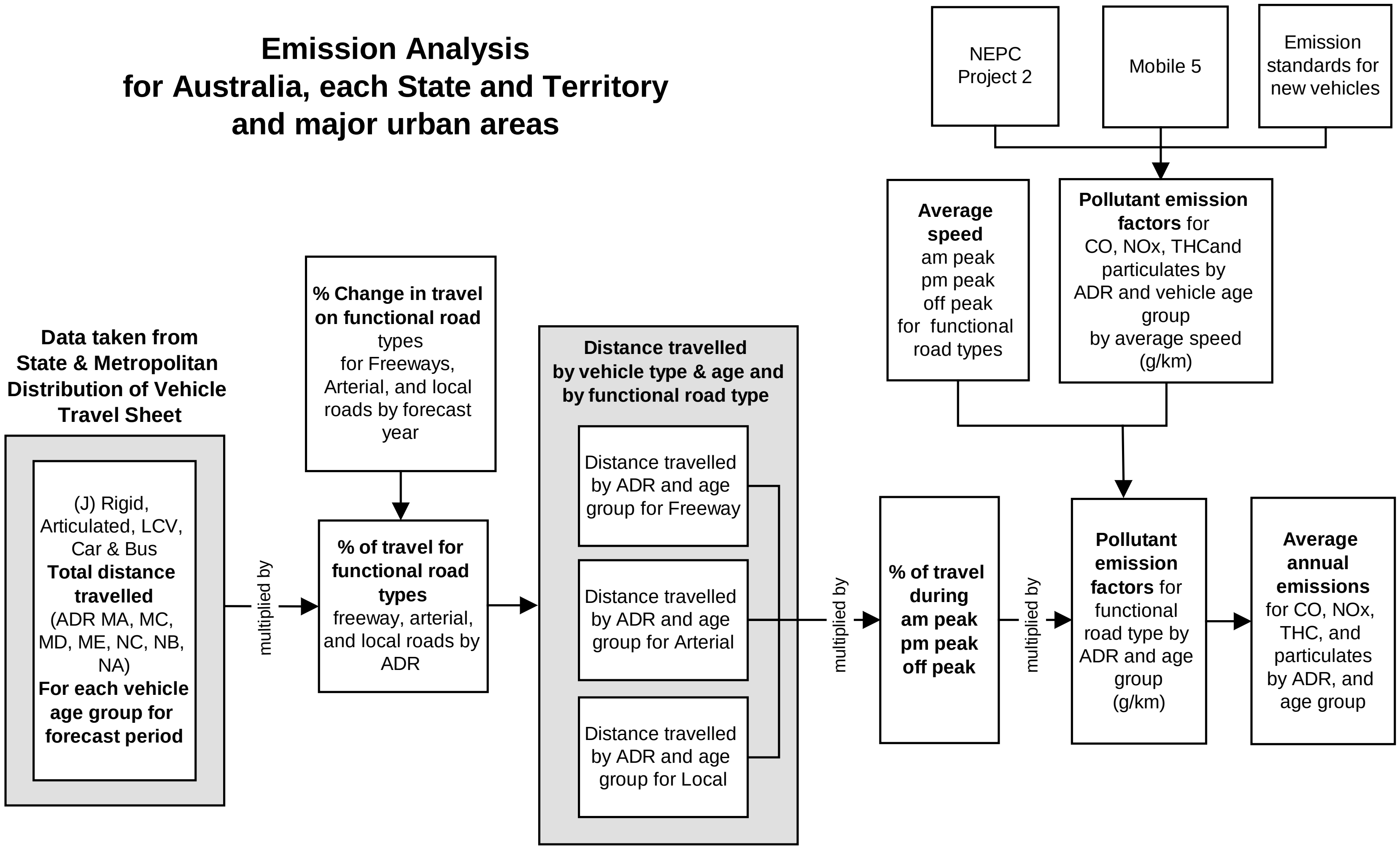
Table 3.9: Estimates of Metropolitan Travel on Functional Road Types

	% Art.>20,000	%Art,<20000	% Total	% Local	Km Freeway	% Freeway	% Arterial
NSW	35.9	23.4	59.3	30.7	97	6.7	62.6
VIC	51.3	18.7	70.0	30.0	191	13.0	57
QLD	34.5	34.3	68.8	31.2	119	18.5	50.3
WA	45.9	33.7	79.6	20.4	50	7.3	72.3
SA	4.4	56.9	61.3	38.7	12	2.2	59.1
TAS	26.2	17.6	43.8	56.2	28	16.5	27.3
NT			69.9	30.1	30.1	0	69.9
ACT		57.8	57.8	42.2	27	16.9	40.9

Source: NRTC 1996, Cox 1997

Notes: 1. This is the % total arterial travel less the % freeway travel.

Flow Chart 4:



Emission Analysis
for Australia, each State and Territory
and major urban areas
NEPC Project 2
Mobile 5
Emission standards for new vehicles
Average speed am peak pm peak off peak for functional road types
Pollutant emission factors for CO, NOx, THCand particulates by ADR and vehicle age group by average speed (g/km)
Data taken from State & Metropolitan Distribution of Vehicle Travel Sheet
(J) Rigid, Articulated, LCV, Car & Bus Total distance travelled (ADR MA, MC, MD, ME, NC, NB, NA) For each vehicle age group for forecast period
% Change in travel on functional road types for Freeways, Arterial, and local roads by forecast year
multiplied by
% of travel for functional road types freeway, arterial, and local roads by ADR
Distance travelled by vehicle type & age and by functional road type
Distance travelled by ADR and age group for Freeway
Distance travelled by ADR and age group for Arterial
Distance travelled by ADR and age group for Local
multiplied by
% of travel during am peak pm peak off peak
multiplied by
Pollutant emission factors for functional road type by ADR and age group (g/km)
Average annual emissions for CO, NOx, THC, and particulates by ADR, and age group

Assumption 2: Percentage of Metropolitan Travel in Daily Periods

The distribution of daily traffic in the peak periods, the inter-peak period and non peak periods has been estimate by the NTPF (1995) and is detailed in Table 3.10. The Adelaide data has been updated by Bray (1995).

Table 3.10: Estimates of Metropolitan Travel in Daily Periods (%)

	Sydney	Melbourne	Brisbane	Perth	Adelaide, Canberra, Hobart,
Peak Periods (3 hrs)	24	29	28	27	26
Inter Peak (7.5 hrs)	52	47	50	48	52
Evening & Other (13.5 hrs)	24	25	22	25	22
Total	100	100	100	100	100

Source: NTPF 1995, Bray 1995

The disaggregation of metropolitan travel by these daily travel periods is required as different travel speeds and therefore different vehicle emission rates occur in these periods. The estimates for Adelaide have been applied to Canberra, Hobart and Darwin. The total travel given for both peak periods has been divided equally between AM and PM peaks.

Assumption 3: Average Speeds on Functional Road Types

Average speeds in the AM peak, the business inter peak and the PM peak are derived each year by Austroads for different functional road types in all metropolitan areas except Hobart and Darwin. These speeds were included in Austroads (1996) for the 1994/95 year but only average metropolitan values are included in their most recent National Performance Indicators benchmarking summary (Austroads 1998). More detailed state/territory reports provide the travel speeds on different functional road types (freeways and arterials), for each daily period (eg Vicroads 1999). Data is also available for divided and undivided roads and inner versus outer urban areas.

Average urban speeds in 1994/95 on all urban roads, as given in Austroads (1997) for different periods of the day, are used for arterial road speeds in each capital city, as most travel is on arterial roads (see **Table 3.9**).

Table 3.11: Estimates of Metropolitan Travel Speeds in Daily Periods on Arterial Roads

	Sydney	Melbourne	Brisbane	Perth	Adelaide/Hobart/ Darwin	Canberra
AM Peak	34.5	37.0	47.6	40.3	40.5	58.8
Interpeak	47.6	44.8	40.0	51.3	46.9	61.9
PM Peak	40.5	40.0	53.1	47.6	43.2	58.9
Nominal	68.2	65.9	71.4	66.7	63.2	75.0
Evening & Other (assumed)	56.1	53.3	65.2	58.0	53.8	67.8

Source: Austroads 1996

Due to a lack of data, it is assumed that the travel speeds in each daily period on freeways is similar to the results quoted for Victoria (Vicroads, 1999). Although no speed measurements are taken in the evening period, a nominal speed based on speed limits is provided. A value for the evening speed is derived from the average of the interpeak and nominal speeds.

Table 3.12: Estimates of Metropolitan Travel Speeds in Daily Periods on Freeways

	Sydney	Melbourne	Brisbane	Perth	Adelaide	Canberra
AM Peak	68.7	68.7	68.7	68.7	68.7	68.7
Interpeak	87.8	87.8	87.8	87.8	87.8	87.8
PM Peak	82.6	82.6	82.6	82.6	82.6	82.6
Nominal	99.0	99.0	99.0	99.0	99.0	99.0
Evening & Other	93.4	93.4	93.4	93.4	93.4	93.4

Source: Vicroads 1999 for Melbourne. All other cities are assumed to be similar to Melbourne

The average speed on rural roads in WA, NT, SA and Queensland is assumed to be 95 km/h and 90 km/h for NSW, Victoria and Tasmania.

Travel speed survey information is not available for the local road system, although it is known that the general speed limit varies from 50 to 60 km/h while speeds near some land use activities such as schools are restricted to 25 km/h. An average speed of 35 km/h on local roads is assumed for all metropolitan cities.

Assumption 4: Proportion of Vehicle Class by Region of Origin and Year of Manufacture

Chapter 2 detailed the percentage of vehicles imported into Australia from the US, Europe and Japan, by vehicle type and year of manufacture. Although there was a considerable change in these proportions during the 1980's, an equilibrium now appears to have been attained. Accordingly, the current percentages will be applied to the forecast period.

The percentage of vehicles by region of origin and by vehicle class will be applied to the vehicle emission rates from each region to derive a weighted average emission rate for each year of manufacture and for each vehicle class.

Assumption 5: Emission Rates by Year of Vehicle Manufacture (g/k)

It was proposed to use the Mobile 5 format of a zero emission rate. However, these deterioration parameters are not available for the more numerous Japanese and European diesel vehicles present in Australia.
A great deal of actual emission information for various vehicle types, years of manufacture and regions of vehicle origin have been collected by EPA NSW and it was decided that this more comprehensive emission data would be used in the analysis. This would also allow a comparison of the model results with Australian studies using similar emission data.

The emission rates shown graphically in Section 2.12, have been entered into the assumption sheet of the VEHICLE EMISSION MODEL while the Mobile 5 deterioration factor has been set to zero.

EPA NSW have also supplied different particulate emission levels based on the three diesel fuel standards which presently exist and those to be introduced over the next seven years – the existing 1500 ppm (0.15%) sulfur diesel, the interim 500 ppm (0.05%) low sulfur diesel and the eventual 50 ppm sulfur fuel (0.005%).

Actual emission data, including deterioration effects, have been input for the five vehicle types, by year of manufacture, the three countries of manufacture and the four selected pollutants. These were averaged for each vehicle type based on the proportion of vehicles in each region (Assumption 4).

Three different sets of emission data have been entered into different versions of the spreadsheet model. The first set was determined by EPA NSW before the recent agreement on diesel standards and was based on existing emission standards and diesel fuel quality. The second set was similar but assumed the introduction of low sulfur fuel. Both of these sets assumed little improvement in diesel engine emissions from 2002 onwards and were used to determine one of the scenarios required by the brief – the effect of the introduction of low sulfur fuel on projected emissions.

The third set of vehicle emission rates was assumed to follow the recently agreed emission standards that will apply in future years for each vehicle type. The modelling was revised to incorporate the different particulate emissions for 500 ppm sulfur fuel between 2003 and 2005 and for the 50 ppm sulfur fuel from 2006 onwards.

The emissions from this third set of emission rates should form the base case for diesel emission projections in Australia from which the effects of any change in policy or economic growth scenario can be determined.

Assumption 6: Variation of Vehicle Emissions with Travel Speed

The variation of vehicle emissions with speed has been estimated using the Mobile 5 diesel emission relationships. This model calculates emissions varying with speed for two vehicles:

- a light duty diesel powered truck - which has been applied to 4WD vehicles, light commercial vehicles and rigid trucks;
- heavy duty diesel powered truck – which has been applied to articulated trucks and buses.

The model determines the variation of emissions with speed as follows:

$$ER\ (myr) = BER\ (myr) * SCF$$

Where

ER = on road emission rate for the specific model year (g/km),

Myr = model year,

BER = baseline emission rate for the model year (g/km),

= ZMER +(DR *M)

where ZMER = the zero mile emission rate (g/km),

DR = deterioration rate/10,000 miles (g/km),

M = miles in ten thousands,

SCF = the speed correction factor for the existing on road average speed,

$= EXP\ (\ B\ (s-s_{adj}) + C\ (s^2\ -\ s_{adj}{}^2))$ for light duty vehicles

$= EXP\ (A\ \ + B*s + C * s^2$ for heavy vehicles

s = the average speed (mph)

sadj = the basic test procedure speed = 16.8 mph = 25.8 kph

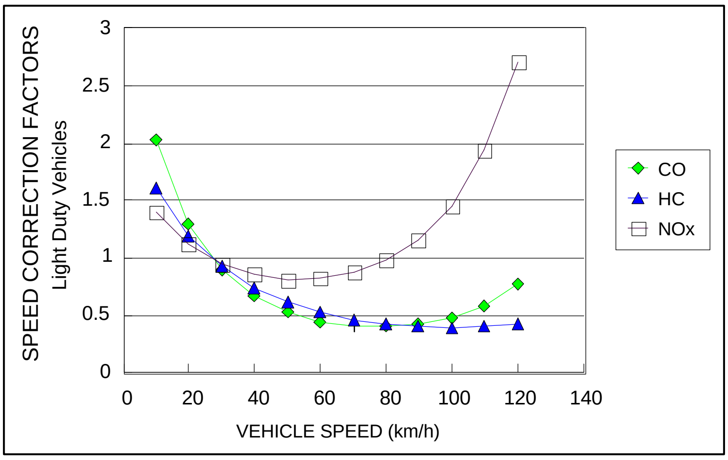
The outcome of the above vehicle emission analyses using the Mobile 5 parameters is given in tabular form for light duty vehicles in **Table 3.13** and in graphical form for both light and heavy vehicles in **Figures 3.10 and 3.11**.

Table 3.13: Mobile 5 Speed Correction Factors Light Trucks

			CO	HC	NOx
Mobile 5	Parameters	A	0	0	0
		B	-0.088	-0.055	-0.048
		C	0.00091	0.00044	0.00071

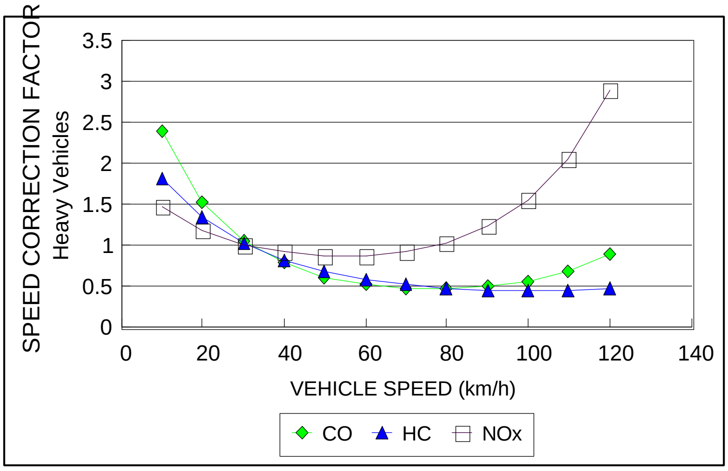
SPEED	CO	HC	NOx
10	2.03	1.61	1.40
20	1.30	1.20	1.12
30	0.90	0.93	0.96
40	0.66	0.74	0.86
50	0.53	0.61	0.82
60	0.45	0.53	0.82
70	0.41	0.47	0.87
80	0.41	0.43	0.98
90	0.43	0.41	1.16
100	0.48	0.40	1.46
110	0.59	0.41	1.94
120	0.77	0.43	2.72

Figure 3.8: Mobile 5 Speed Correction Factors for Light Duty Vehicles



Source: US EPA

Figure 3.9: Mobile 5 Speed Correction Factors for Heavy Duty Vehicles



Source: US EPA

Figures 3.8 and 3.9 demonstrates that minimum emissions for CO and HC from both light and heavy vehicles are achieved at speeds of 80 km / hr to 90 km / hr while minimum emissions for NOx are at speeds between 50 km / hr and 60 km / hr.

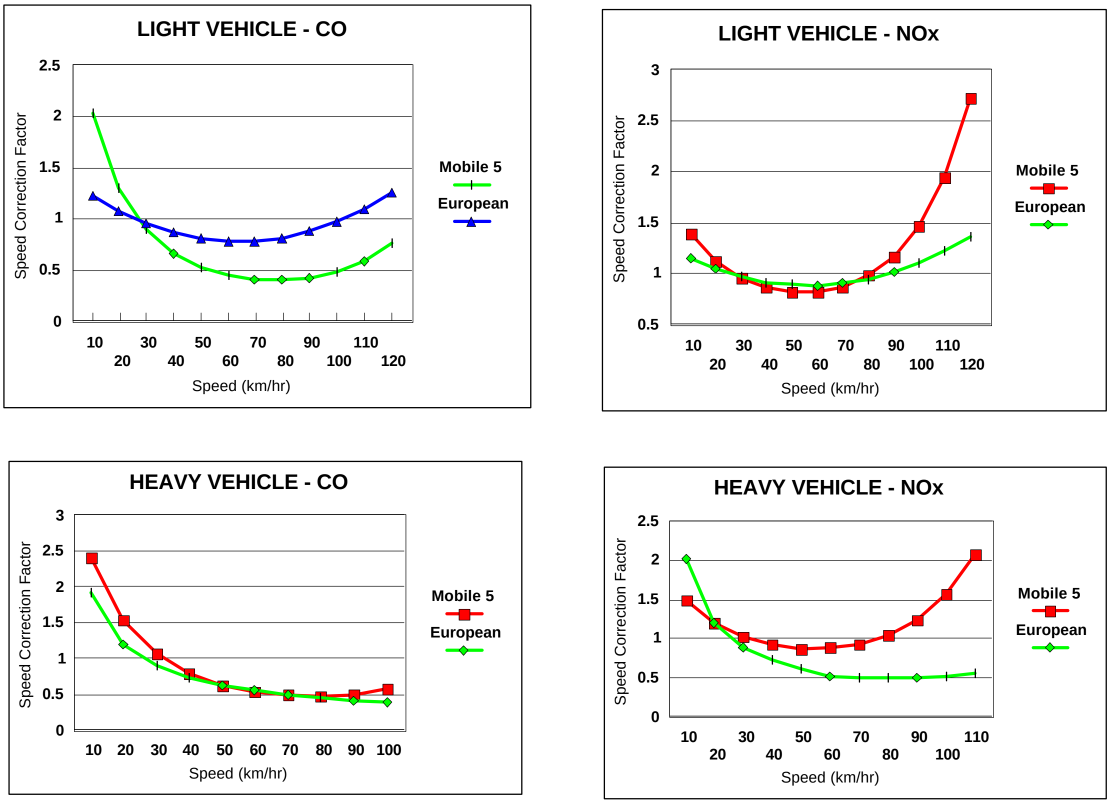
A comparison of US EPA (Mobile 5) and European Environmental Agency[1] speed correction factors has been made and the results are given graphically in Figure 3.10 below. For light vehicles the European figures indicate less of a reduction in CO than the US at higher speeds but a close agreement for NOx over normal urban operating speeds. Mobile 5 gives, however, much higher NOx emissions for light vehicles at speeds greater than 90 km / h, as occurs in rural areas. It should be noted that the speed range for minimum emissions are similar for both the US and European speed emission relationships.

For heavy vehicles there is a closer agreement in CO emission factors but Mobile 5 again gives higher NOx emissions at higher speeds than the European factors. The Mobile 5 NOx emissions are, however, lower than the European factors at lower speeds.

No revisions will be made to the Mobile 5 speed correction factors based on these European factors but it should be borne in mind that if the European factors are closer to reality then there will be an underestimation of CO emissions in urban areas where a large percentage of the lighter vehicles operate and an overestimate of NOx in rural areas where a large percentage of articulated trucks is operating at high speeds.

[1] Personal communication, European Environmental Agency, John Apelbaum, 1997

Figure 3.10: A Comparison between Mobile 5 and European Environment Agency Speed Correction Factors



Source: European Environment Agency, US EPA

The emission rates of the EPA NSW are generally used in that State with overall travel figures and without any speed correction factor to determine emission levels. The Mobile 5 speed correction value of 1 is at a test procedure of 25.8 km/h and this is considerably lower than the average urban speed in Australian capital cities of between 40 and 45 km/h. Hence the speed correction calculations could result in significantly lower emissions for this study than the emissions estimated by EPA NSW. This is particularly the case for CO and HC pollutants, where the speed correction factors at 60 km/h would give only half the EPA emission rates.

As the given NSW EPA emission rates are meant to apply to normal operating conditions, Mobile 5 speed correction factors have been adjusted to give a speed correction factor of 1.0 for all pollutants at 40 km/h rather than at 25.8 km/h. These revised speed correction factors are given in the following two figures.

Figure 3.11: Revised Mobile 5 Speed Correction Factors for Light Duty Vehicles

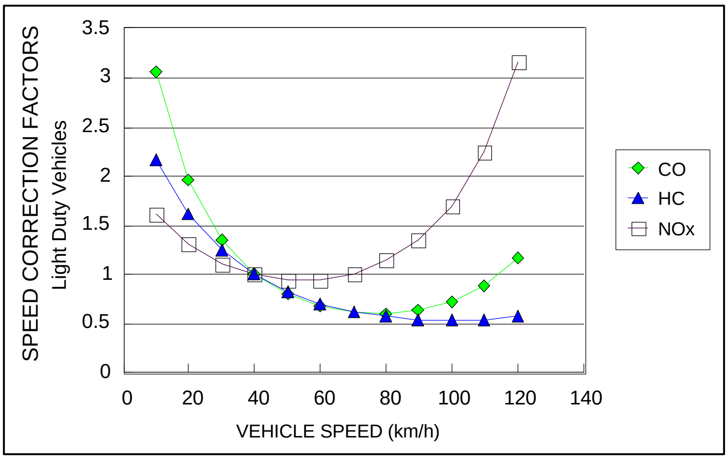
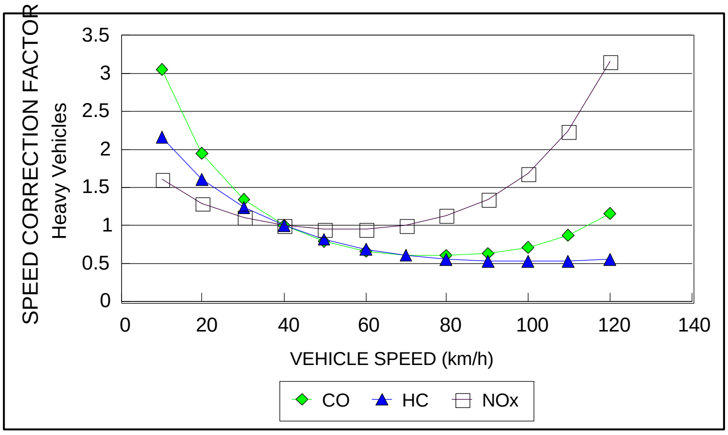


Figure 3.12: Revised Mobile 5 Speed Correction Factors for Heavy Duty Vehicles



Assumption 7: Deterioration Relationships

Mobile 5 derives the deterioration in emissions based upon the cumulative mileage undertaken by vehicles since their year of manufacture. The cumulative kilometres is estimated from the vehicle age (years), the vehicle life (years) and the total cumulative kilometres during the vehicles life, for each vehicle class. Given the linear reduction of travel by vehicle age (see Figures 2.1 to 2.4), it is assumed that there is a linear decrease in annual utilisation during the life of the vehicle. Accordingly, the cumulative kilometres at any vehicle age (N) of the vehicle life (L) can be calculated as:

$$CKT_N = CKT_L - AKT1 * (L-N)^2 / (2* L)$$

Where

CKT_N = the cumulative travel in km at vehicle age N in years

CKT_L = the cumulative travel in km at the end of the vehicle life L in years

L = the vehicle life in years

AKT1 = annual distance travelled at year 1

= $2 * CKT_L / L$

The vehicle parameters chosen are detailed in **Table 3.14**.

Table 3.14: Distance Travelled Parameters

Vehicle Class	Vehicle Life – L (yrs)	Lifetime Cumulative CKT$_L$ ('000 KM)	Annual Distance Travelled in First Year (km)
Cars	18.6	266	28,600
LCV	18.6	321	34.500
Rigid Trucks	16.5	390	47,300
Articulated Trucks	15.7	1350	172,000
Buses	18.3	610	66,600

Source: Cox / Arup 1995

Note: 1. The vehicle life and cumulative kilometres are at 90 per cent of the total cumulative kilometres, representing a service life.

If travel exists beyond the assumed vehicle lives then the lifetime cumulative kilometres given in the above table are used to calculate the deterioration parameters.

As discussed previously, the deterioration rates used in the model allow for deterioration and the spreadsheet assumes a zero deterioration rate.

3.5.2 EMISSION MODELS

The annual emissions for any of the selected pollutants by metropolitan or non-metropolitan area and vehicle type is estimated as follows:

Annual emissions = ☒(vc=1 to 5) ☒ (myr =1976 to 2015) ☒ (frt =1 to 4) ☒ (dp = 1 to 4) VKT (vc) X ER (vc, BER, SCF)

Where vc = vehicle class (vc1 = cars, vc2 = LCV, vc3 = rigid trucks, vc4 = artic trucks, vc5 = buses

myr = year of manufacture (from 1976 onwards)

frt = functional road type (frt1 = freeways, frt2 = arterials, frt3 = local roads)

= rural roads only when estimating non-metropolitan emissions

dp = daily period (dp1 = AM peak, dp2 = business interpeak, dp3 = PM peak, dp4 = evening

ER = emission rate (g / km)

BER = baseline emission rate = Zero mile emission rate + DR X M

DR = deterioration rate per 10,000 miles (g / km)

M = vehicle miles in ten thousands

SCF = speed correction factor based on SCF = 1.0 at average urban average speed of 40 km / h

$= EXP (B (s-s_{adj}) + C (s^2 - s_{adj}{}^2))$

s = average speed (mph)

sadj = basic test procedure speed = 16.8 mph = 25.8 kph

Annual emissions in the following year of the forecast period is derived from the distribution of travel in that year for each vehicle type and revisions to the emission rate by increasing vehicle age by one year.

3.6 USE OF MODEL SPREADSHEETS

Travel Demand
The calculation of travel demand in all States can be made by the normal F9 key. The various charts and tables for all States and Australia as a whole can be inspected by going into the various spreadsheet tabs at the bottom of the spreadsheet. The printing of the various travel demand results will be controlled from the PRINT MACROS spreadsheet which is the first spreadsheet in the set and is shown in **Figure 3.13**. The left hand side of this spreadsheet controls the printing of National travel charts while those at the bottom control printing of the forecast travel by vehicle type. The printing of metro travel charts is carried out by choosing the State required and then clicking the metro travel chart button in the middle left of this PRINT MACROS sheet. Tables of national freight and national travel over the forecast period can also be printed out.

If assumptions or data used for travel estimates are changed then recalculation using the F9 key needs to be carried out.

Emission Calculations
In contrast to the travel demand calculations, emission calculations can only be carried out State by State after the State is chosen and made active in the emissions section of this PRINT MACROS spreadsheet. This section is in the middle right of the PRINT MACRO spreadsheet and it is necessary to select the red "**Update emission chart and summaries for all years of selected State**" to produce results for the particular State chosen. The emission results for this State can also be reviewed by going into the spreadsheet tabs for the charts and tables for the selected State.

Any printing of emission charts or tables of emissions has to be carried out before another State is chosen as the charts and tables for that State are replaced when a new State is chosen. The reason for this is that it is not possible to keep emission records for all States and regions in the one spreadsheet because of capacity considerations.

The emission calculations for one State take about 40 seconds on a 100 mHz microcomputer and 8 seconds on a 330 mHz microcomputer.

After the calculations several "black" buttons can be used to print the following results:

- One emission summary table can be printed for a selected year of this State;
- More detailed emission results for this year by functional road type, travel period and year of forecast;
- A summary of total emissions by individual pollutant for all years between 1995 and 2015 for both metropolitan and rural regions for the selected State;
- Charts of the above data for the selected State; and
- Detailed summaries of all years of the forecast period.

Figure 3.13: PRINT MACRO Spreadsheet

Chart and Table Print Buttons

National Travel Charts

- Total Travel Charts (6)
- Diesel Travel vkm Charts (6)
- Diesel Travel % Charts (6)
- Fleet Charts (6)
- Freight Charts (4)
- Distribution of Travel Charts (4)

Metro Travel Charts

Select State then click button

- (●) Australia
- ( ) NSW
- ( ) VIC
- ( ) QLD
- ( ) WA
- ( ) SA
- ( ) TAS
- ( ) NT
- ( ) ACT

- Metro Travel Charts (6)

National Table Print Buttons

- National Freight Tables
- National Travel Tables

Emissions Summary Tables and Charts

Year: 2015

State: NSW

- Print Total Emission Table for selected State
- Update Emission Chart & Summaries for ALL years of selected State
- Print Total Emission Charts for selected State
- Print one Emission Summary for selected Year and State
- Print 20 Emission Summaries, for ALL years of selected State

CAR Travel Tables

- Tables D1, D2, D3
- Tables D4, D5, D6
- Tables D7, D8, D9

LCV Travel Tables

- Tables E1, E2, E3
- Tables E4, E5, E6
- Tables E7, E8, E9

Rigid Truck Travel Tables

- Tables F1, F2, F3
- Tables F4, F5, F6
- Tables F7, F8, F9

Artic Truck Travel Tables

- Tables G1, G2, G3
- Tables G4, G5, G6
- Tables G7, G8, G9

Bus Travel Tables

- Tables H1, H2, H3
- Tables H4, H5, H6
- Tables H7, H8, H9

YearTable

1	1996
2	1997
3	1998
4	1999
5	2000
6	2001
7	2002
8	2003
9	2004
10	2005
11	2006
12	2007
13	2008
14	2009
15	2010
16	2011
17	2012
18	2013
19	2014
20	2015

StateNames

1	NSW
2	VIC
3	QLD
4	WA
5	SA
6	TAS
7	NT
8	ACT

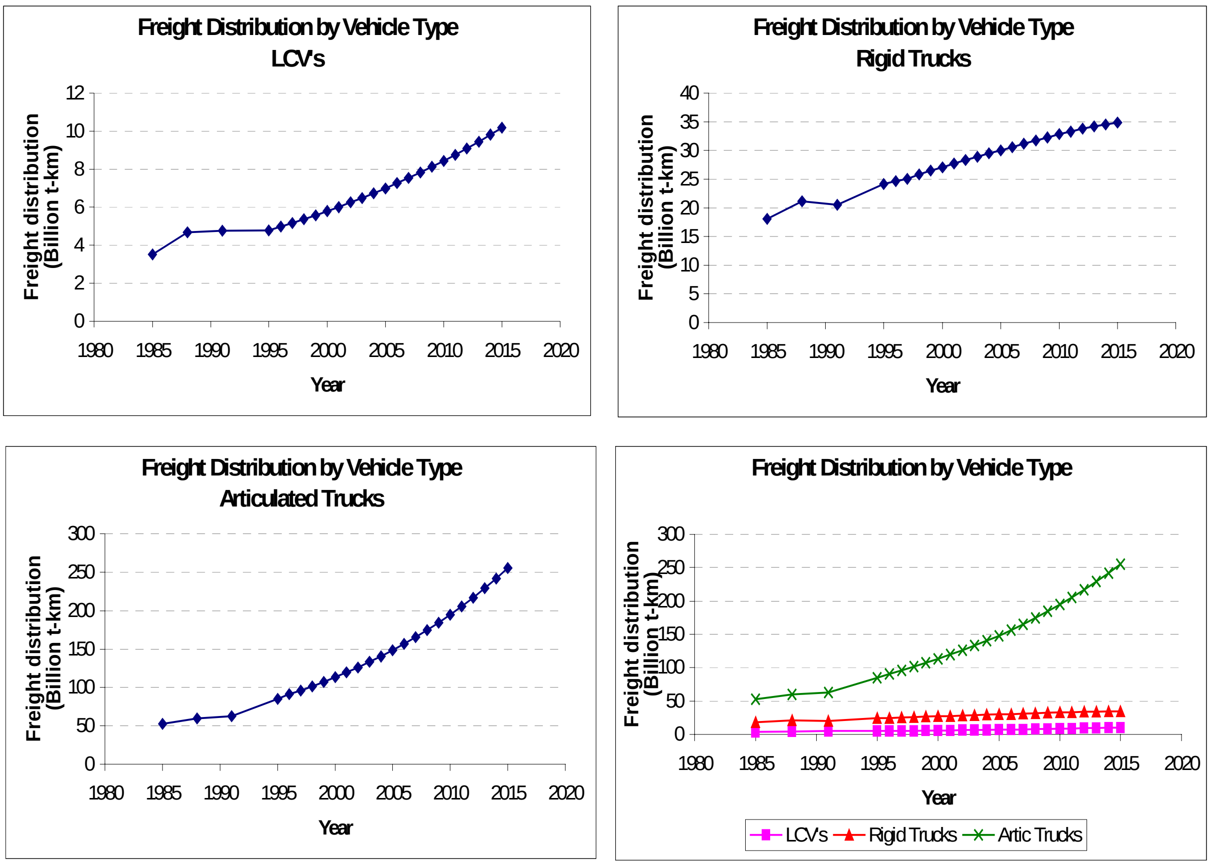
4. TRAVEL DEMAND FORECASTS

The purpose of this section of the report is to present the forecasts of national travel demand, the vehicle fleet, metropolitan travel and the distribution of diesel travel from diesel vehicles. The forecasts of freight demand include the reduction in prices for diesel fuel in the recent Australian New Tax System that was agreed with the Democrats. This is called ANTS II to distinguish it from the original tax reform proposal (ANTS I). No change in the assumed 3.2% annual GDP growth rate over the forecast period due to the ANTSII package was taken as this has been estimated to be only 1.8% over a 5 to 10 year period (Tsolakis et al 1998).

4.1 NATIONAL FREIGHT AND TRAVEL DEMAND

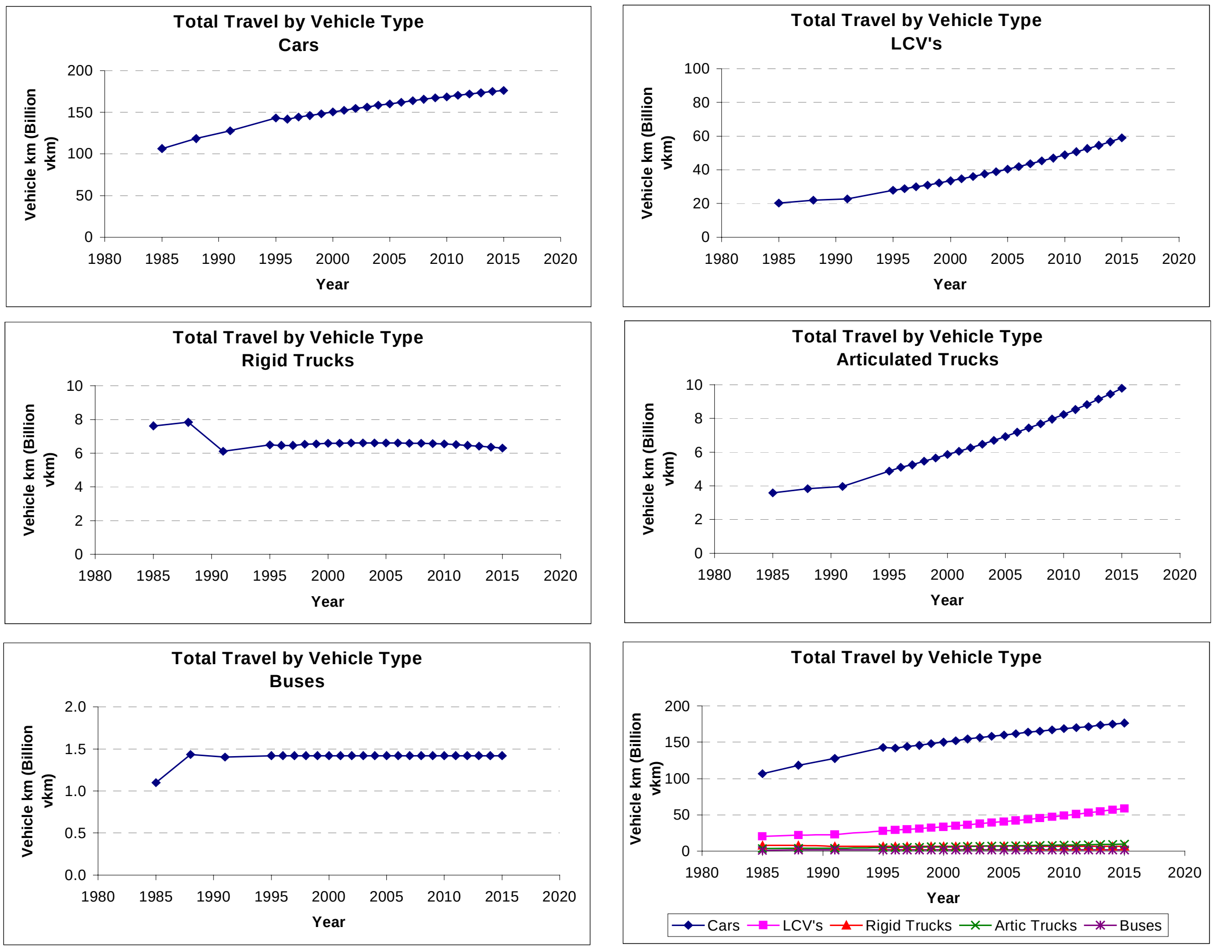
The national **freight** demand (in billion tonne kilometres) for LCVs, rigid and articulated trucks is shown in **Figure 4.1** while detailed results in tabular form are given in Appendix E. The 1985, 1988, 1991 and 1995 results are actual freight movements (see section 2) while the results from 1996 onwards are forecasts. The figures demonstrate that while there are appreciable increases in the freight carried by light commercial vehicles and rigid trucks, the majority of the increased freight movement will be undertaken by articulated trucks.

Figure 4.1: National Freight Demand Forecasts for Freight Vehicles



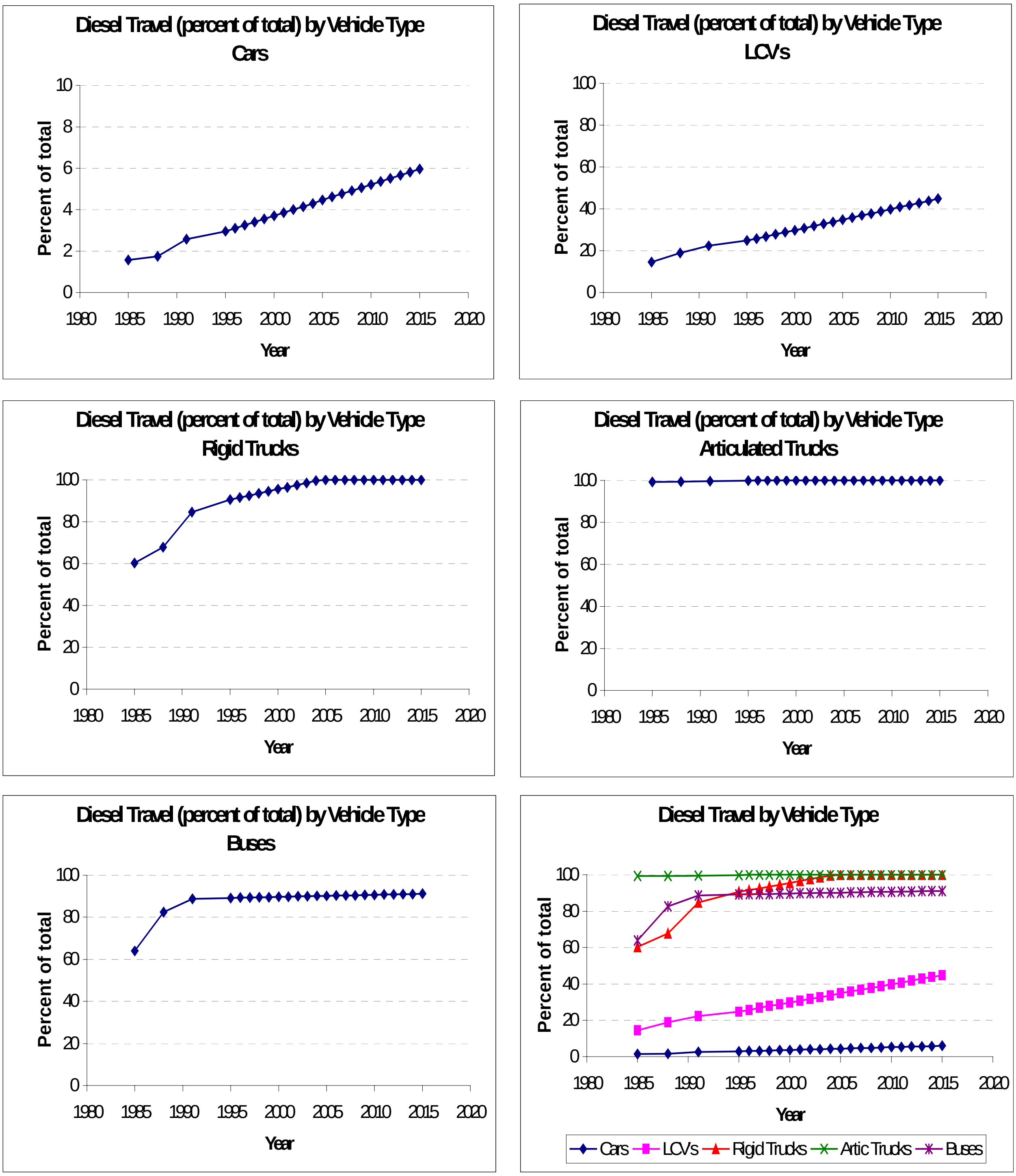
The national **travel** demand for all petrol, gas and diesel powered vehicles by vehicle type is illustrated in **Figure 4.2** while detailed results in tabular form are given in Appendix E. It is seen that the greatest percentage increase in travel is expected from LCVs and articulated trucks while little or no increase in travel is anticipated from rigid trucks and buses.

Figure 4.2: Travel Demand Forecasts for All Vehicles



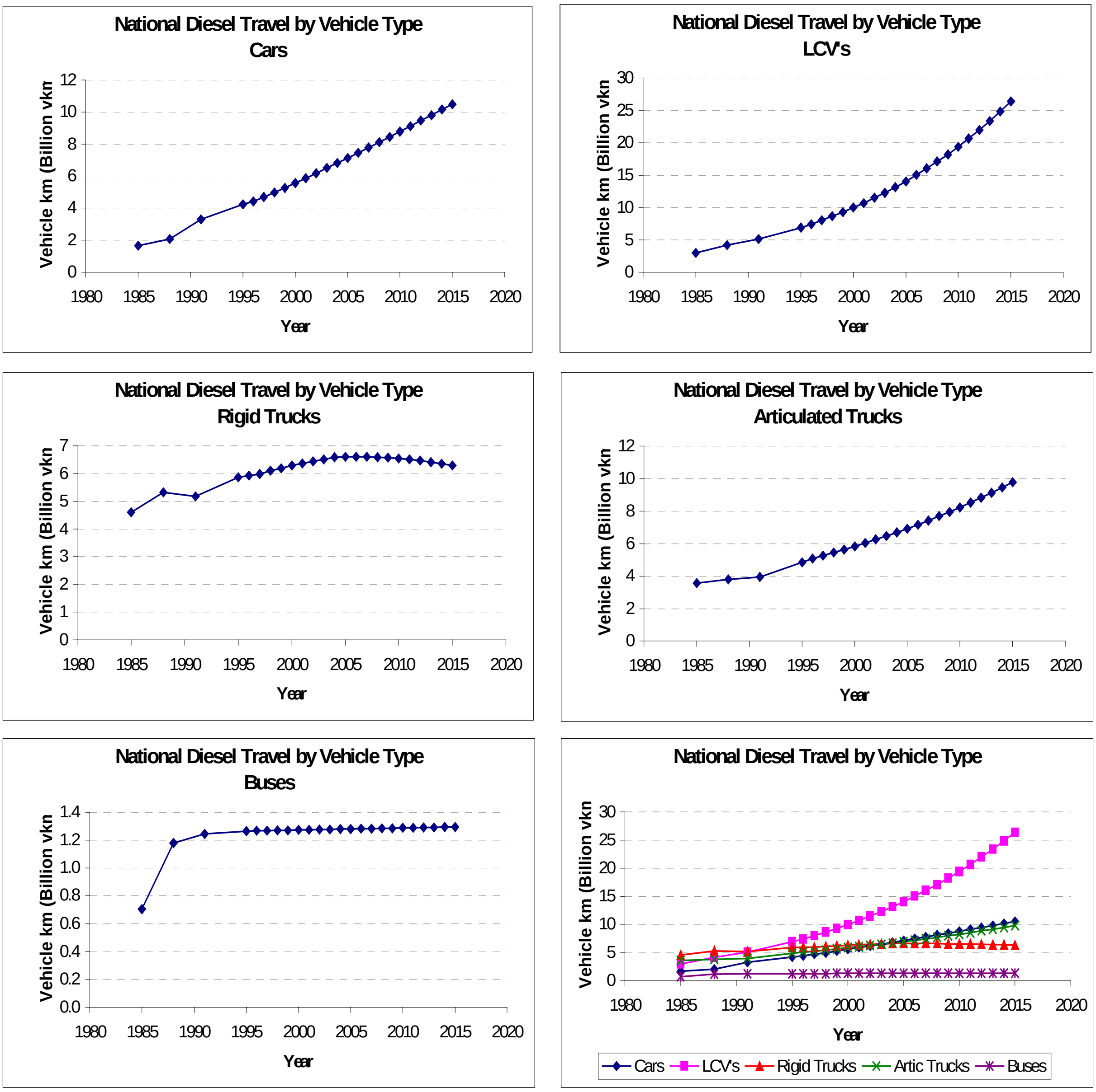
The historical and projected changes in the **percentage of total travel by diesel vehicles** is shown in **Figure 4.3** while detailed results in tabular form are given in Appendix E. It is evident that cars, LCVs and rigid trucks are expected to achieve significant increases in the percentage of diesel travel to total travel.

Figure 4.3: Historical and Assumed Percentage of Total Travel for Diesel Vehicles



The actual **travel of diesel vehicles** (which is the result of combining Figures 4.2 and 4.3) is shown on **Figure 4.4** while detailed results in tabular form are given in Appendix E. It is evident that the greatest increase in diesel travel will be derived from LCVs but that cars and articulated trucks will also contribute to the increase.

Figure 4.4: Travel Demand Forecasts for Diesel Vehicles



The estimated metropolitan and total distance travelled by the diesel vehicle fleet at various vehicle ages is given in the table below for the start and end of the analysis period. The table shows that although 25% of the vehicle fleet is greater than 16 years old this vehicle population only provides 6 to 8% of diesel travel.

Table 4.1: Distance Travelled by Vehicle Age Group for Australian Diesel Fleet

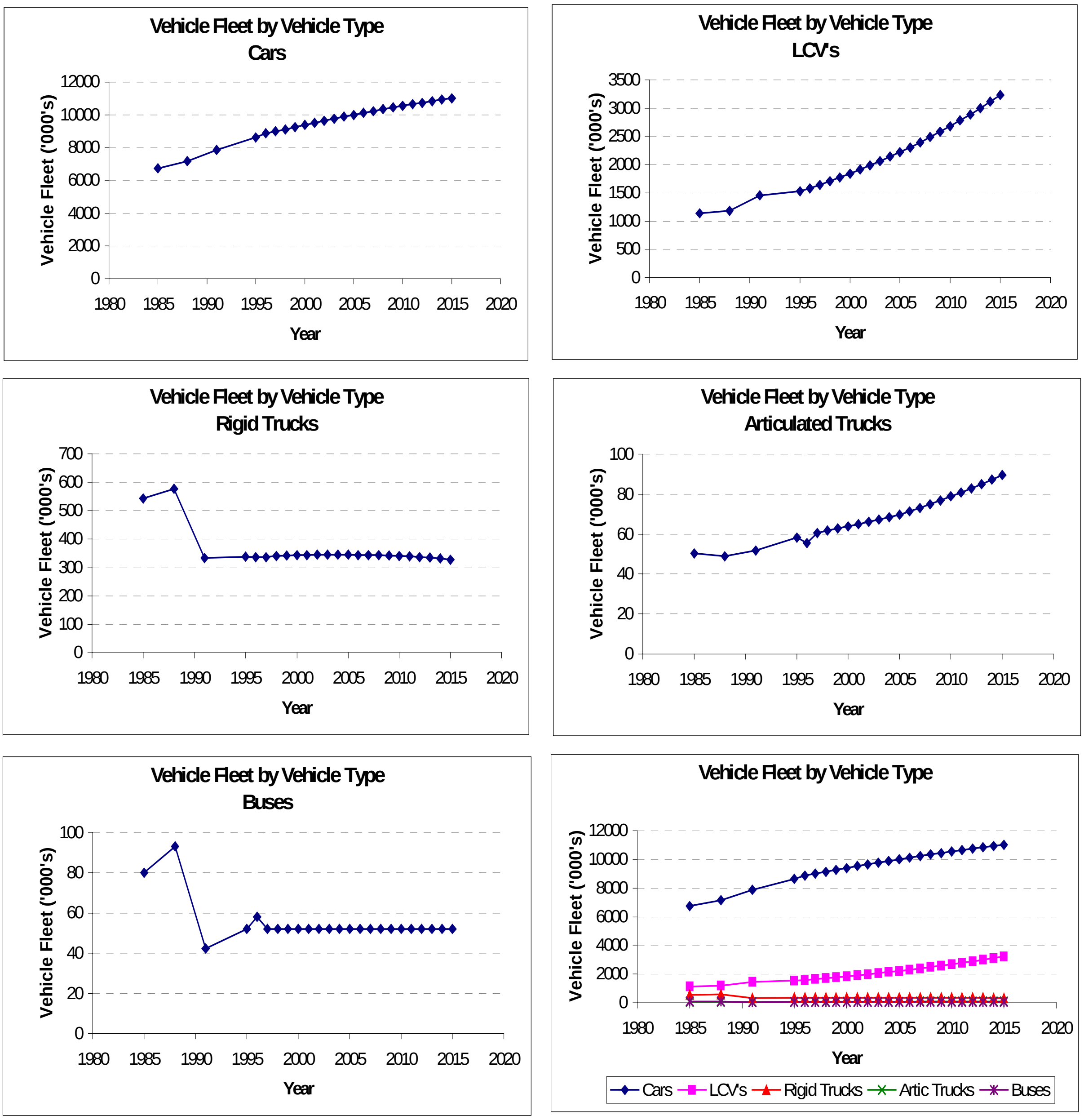
Vehicle Age (years)	% of total diesel fleet population	Metro distance travelled millions km 1996(1)	Metro distance travelled millions km 2015	Total distance travelled millions km 1995	Total distance travelled millions km 2015
0-3	26	2,417 (27)	6,354 (29)	6,296 (27)	16,374 (30)
4-6	14	1,959 (22)	4,867 (22)	4,545 (20)	12,224 (22)
7-10	18	2,096 (24)	5,097 (23)	5,699 (25)	12,646 (23
11-15	18	1,688 (19)	4,003 (18)	5,025 (22)	9,719 (17)
16-20	6	658 (7)	1,410 (6)	1,359 (6)	3,123 (6)
>20	19	67 (1)	100 (1)	293 (1)	188 (0.3)
Totals	100	8,888	21832	23,217	54,275

Notes: 1. 1996 is used for metropolitan travel as 1995 data is not available for all vehicle categories.
2. ( ) signifies % of total diesel for column.

4.2 NATIONAL VEHICLE FLEET

The vehicle fleet required to undertake the forecasts of total national travel demand is shown in Figure 4.5 below, together with existing vehicle numbers for 1985, 1998, 1991 and 1995. The analyses suggest that little growth in the number of buses and rigid trucks is expected. The greatest increase in vehicle numbers will come from cars (2.6 million), LCVs (1.7 million) and articulated trucks (some 30,000).

Figure 4.5: National Vehicle Fleet Forecasts



This diesel travel demand was also used to estimate the number of vehicles needed to satisfy this demand, as shown in the following table. It is seen that the diesel vehicle fleet is estimated to grow from 8.3% of the total vehicle fleet to 15% of the total fleet by 2015.

Table 4.2: The Existing and Forecast Diesel Fleet

Vehicle Type	Total Number of All Vehicles 1995	Total Number of All Vehicles 2015	Number of Diesel Vehicles 1995	Number of Diesel Vehicles 2015
Passenger Vehicles	8,608,906	11,021,000	223,387 (2.6)	556,870 (5)
Light Commercial	1,566,868	3,236,000	332,932 (21.2)	1,280,170 (40)
Rigid / Other Trucks	351,154	327,690	253,968 (72.3)	264,360 (81)
Articulated Trucks	57,939	89,460	56.906 (98.2)	87,890(98)
Buses	45,511	52,170	37,338 (82.0)	38,180 (73)
Total	10,922,746	14,726,320	904,529 (8.3)	2,226,480 (15)

( ) signifies % of diesel vehicles to the total number of vehicles in this vehicle category

4.3 METROPOLITAN DIESEL VEHICLE TRAVEL DEMAND

The travel forecasts for diesel vehicles in the NSW and Victorian metropolitan areas are provided in **Figures 4.6 and 4.7** respectively.

Figure 4.6: Metropolitan Vehicle Travel Demand Forecasts, NSW

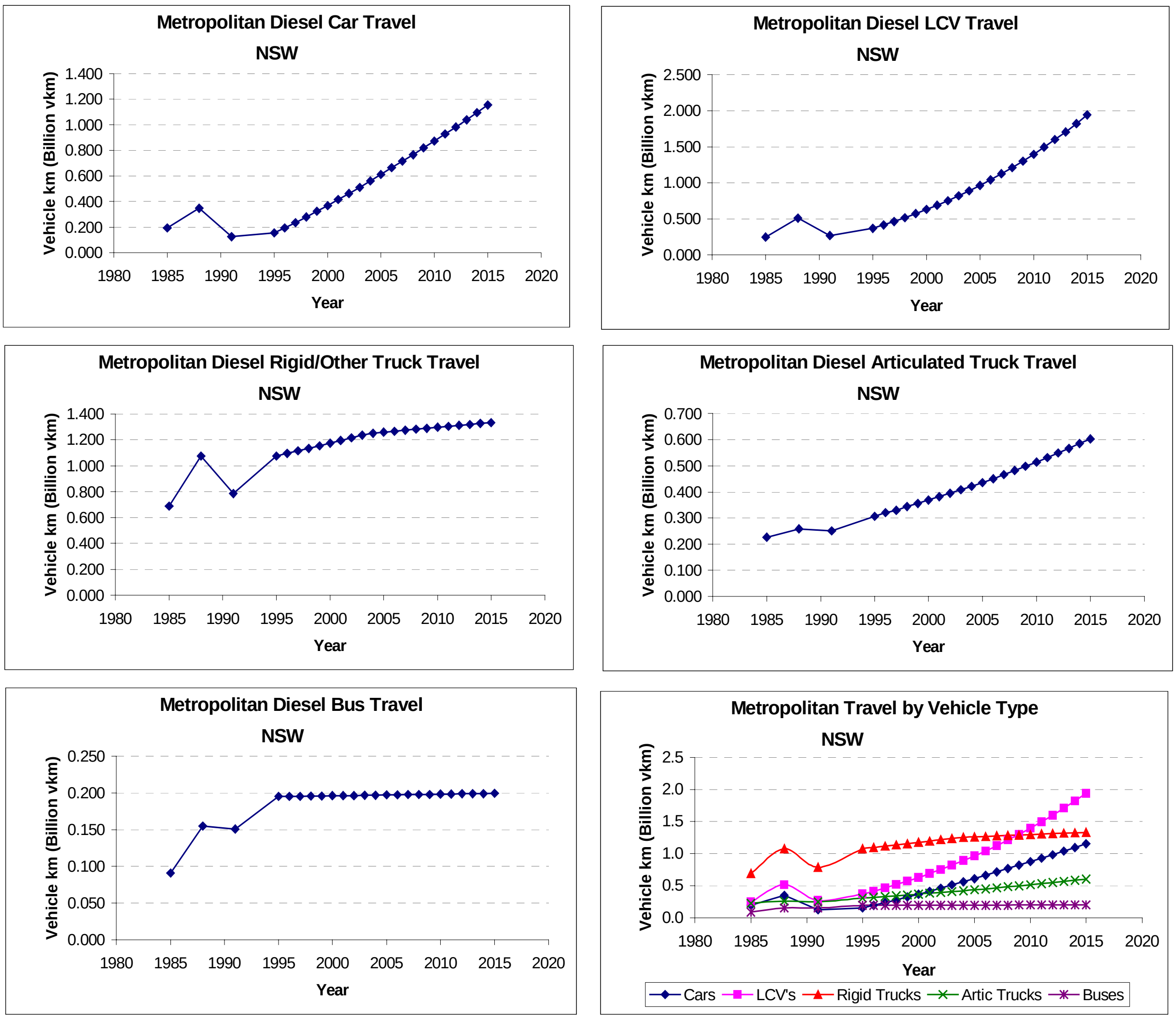
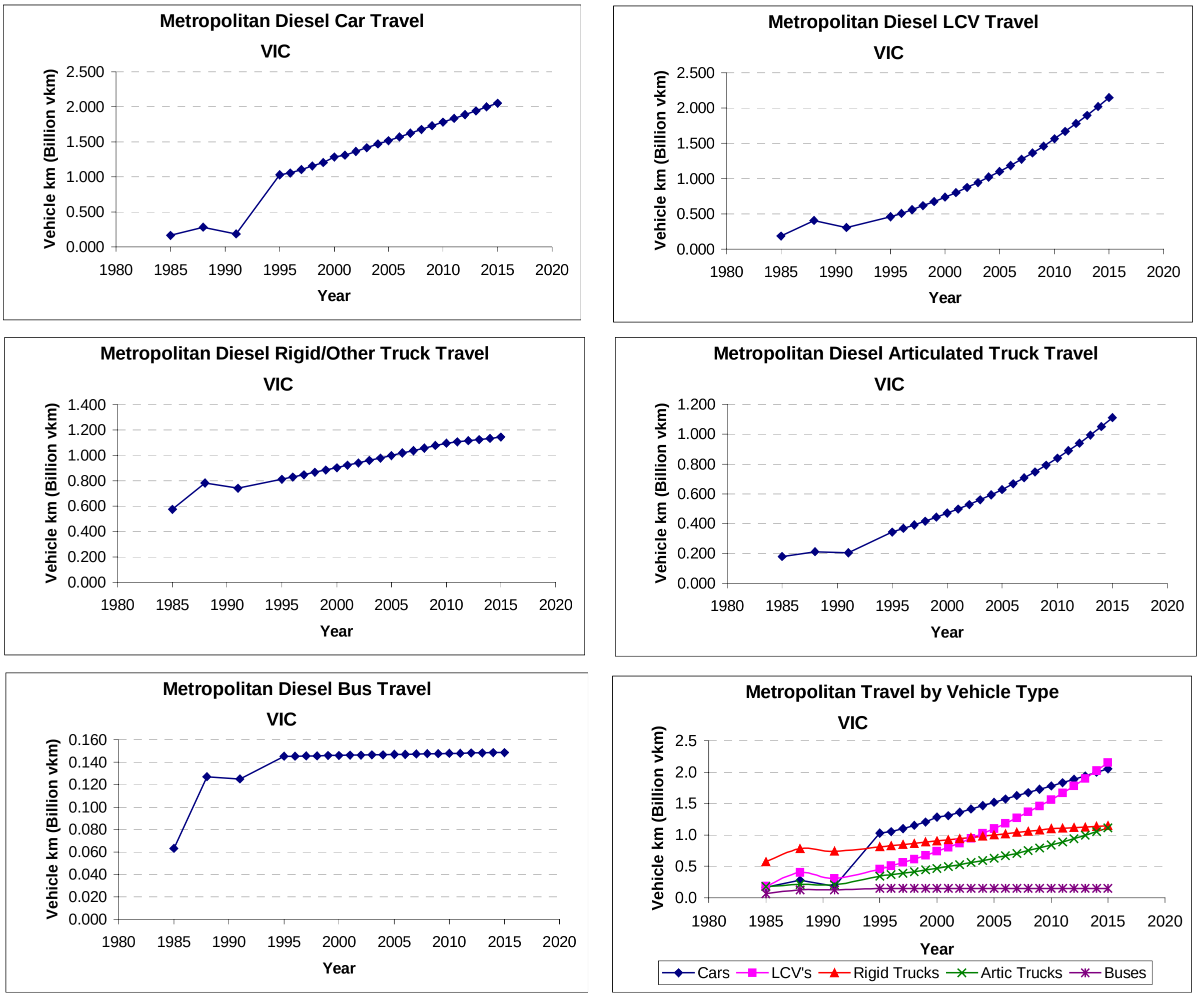


Figure 4.7: Metropolitan Vehicle Travel Demand Forecasts – Victoria



The estimates of metropolitan travel for diesel vehicles in both Sydney and Meolbourne indicate that the major percentage and absolute increases in travel are expected to arise from cars and LCV's.

An analysis of estimated distance travelled by diesel vehicles in metropolitan areas at the start and end of the analysis period is given in the following table and indicates that by 2015 light commercial vehicles will become the dominant diesel vehicle category, accounting for 43% of the total annual distance travelled in metro areas. The percentage of distance travelled by rigid trucks will decline from 34% of all diesel travel in 1996 to 18% in 2015 as freight forwarders continue to switch to the use of articulated vehicles.

Table 4.3: Metro Distance Travelled by Vehicle Type and Age for Australian Diesel Fleet.

		Distance Travelled by Age Millions vehicle - km						Total (% metro diesel)
Vehicle Type	**Year**	**0-3**	**4-6**	**7-10**	**11-15**	**16-20**	**>20**	
Passenger Vehicles	1996 (1)	598.7	452.4	471.6	378.0	142.6	---	2043.2 (23)
	2015	1605.3	1213.0	1264.5	1013.6	382.4	---	5478.8 (25)
Light Commercial	1996	668.1	477.2	487.8	371.2	112.4	4.2	2121.0 (24)
	2015	2945.9	2104.2	2151.0	1636.6	495.7	18.7	9352.0 (43)
Rigid Trucks	1996	612.1	642.7	748.0	658.0	336.7	63.0	3060.5 (34)
	2015	789.4	828.9	964.6	848.6	434.2	81.3	3946.9 (18)
Articulated Trucks	1996	354.5	248.8	244.6	165.8	22.8	---	1036.5 (12)
	2015	825.9	579.6	569.9	386.4	53.1	---	2415.0 (11)
Buses	1996	183.6	138.7	144.6	115.9	43.7	---	626.6 (7)
	2015	187.2	141.4	147.4	118.2	44.6	---	638.8 (3)
Totals	1996	2417.0	1959.8	2096.6	1688.9	658.2	67.3	8887.8
	2015	6353.7	4867.1	5097.5	4003.4	1410.0	100.0	21831.6

Note: 1. 1996 is used for metropolitan travel as 1995 data are not available for all vehicle categories.
2. --- signifies negligible.

Detailed forecasts of diesel travel by vehicle type for all States, and for both metropolitan and rural areas, are given in tabular form in Appendix F.

4.4 DISTRIBUTION OF DIESEL TRAVEL

Examples of the output of the DISTRIBUTION OF VEHICLE TRAVEL MODEL is shown in **Figures 4.8 and 4.9**. The figures give forecasts for the years 1996, 2005 and 2015 of LCV travel in the NSW metropolitan area by vehicle age and forecasts of articulated truck travel by vehicle age in non-metropolitan NSW.

Detailed forecasts of the distribution of vehicle travel for all vehicle types and vehicle ages are given in Appendix F.

Figure 4.8: Distribution of Light Commercial Travel by Vehicle Age - Metropolitan NSW

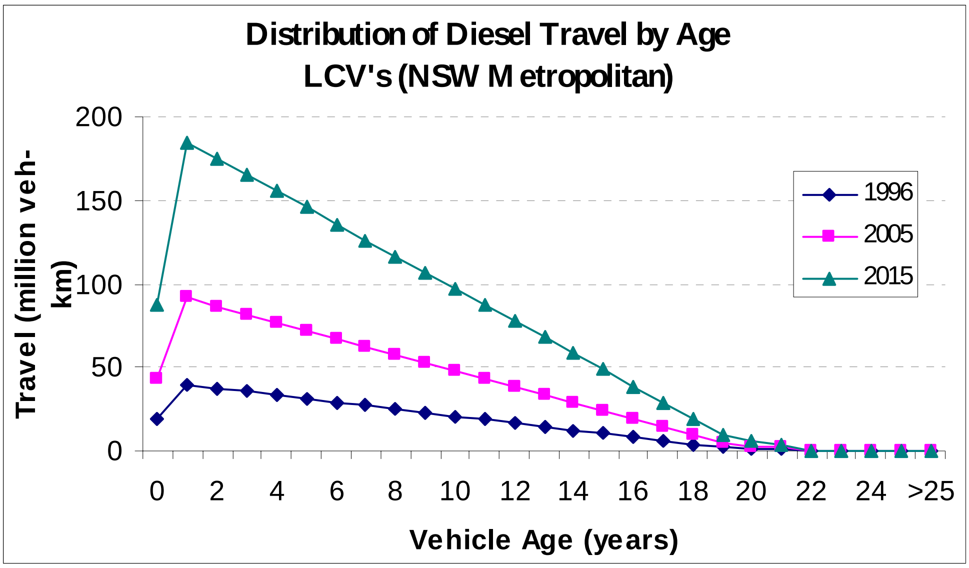
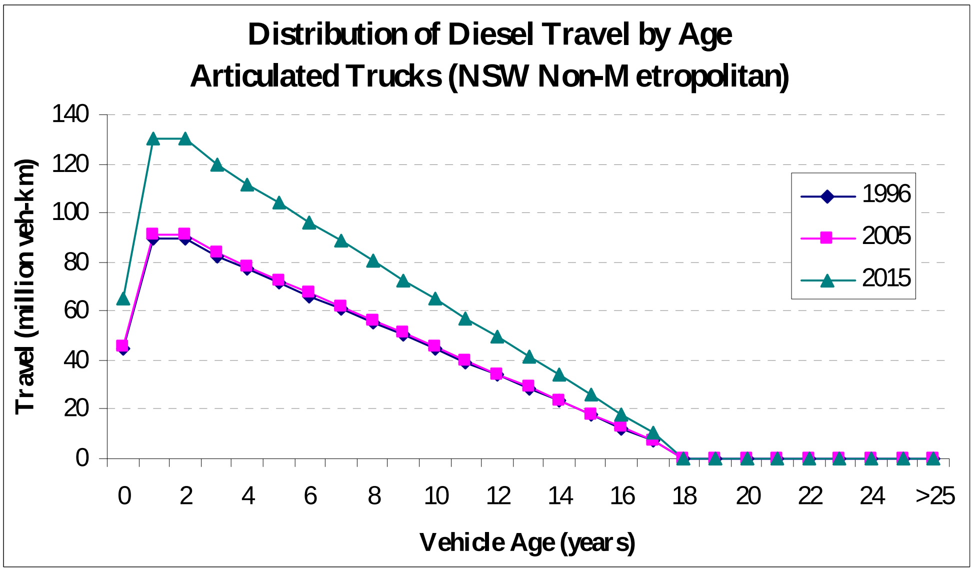


Figure 4.9: Distribution of Articulated Truck by Vehicle Age – Non Metropolitan NSW



5. VEHICLE EMISSION FORECASTS

5.1 SCENARIO ANALYSES

The brief required that the following emission scenarios be examined:

- Euro II / US 94 emissions standards commencing in 2002 without changes to the characteristics of diesel fuel.
- Euro II / US 94 emissions standards commencing in 2002 together with a reduction in the sulfur content of diesel fuel from 0.15 per cent to 0.05 per cent (commencing in 2002).
- The effect of the reduction in emissions due to an inspection and maintenance program which corrects poorly tuned or diesel engines which have been tampered with.

Since the preparation of the terms of reference for the project, these scenarios have become outdated because of the emission and fuel standards agreed upon in the "Measures for a Better Environment" component of the ANTS II tax reform package. We will therefore analyse the difference in emissions under the following scenarios:

- Scenario I: No improvement in emission standards and no change in fuel from the existing 0.15% sulfur. It will be assumed that the estimated emission rates for 2002 vehicles will continue as the new vehicle rate until 2015 in this scenario.
- Scenario II: No improvement in emission standard beyond the year 2002 but a reduction in diesel sulfur content from 0.15% to 0.05% commencing in this year. This scenario using low sulfur fuel will use different particulate emission rates for the 0.05% sulfur fuel commencing in 2002 but will apply the same emission rates for CO, HC and NOx, as there is insufficient empirical data to reduce these pollutant emission rates because of a difference in sulfur content.
- Scenario III: Measures for a Better Environment including:
  - introduction of Euro 2 for light duty vehicles (cars, LCV's) and Euro 3 or US 98 emission standards for heavy duty vehicles (buses, trucks) in 2002/3;
  - introduction of Euro 4 or US 2004 emission standards for all vehicles in 2006/7; and
  - a change from existing 0.15% (1500 ppm) sulfur diesel to 0.05% (500 ppm) sulfur from 2003 and to 0.05% (50 ppm) sulfur from 2006.

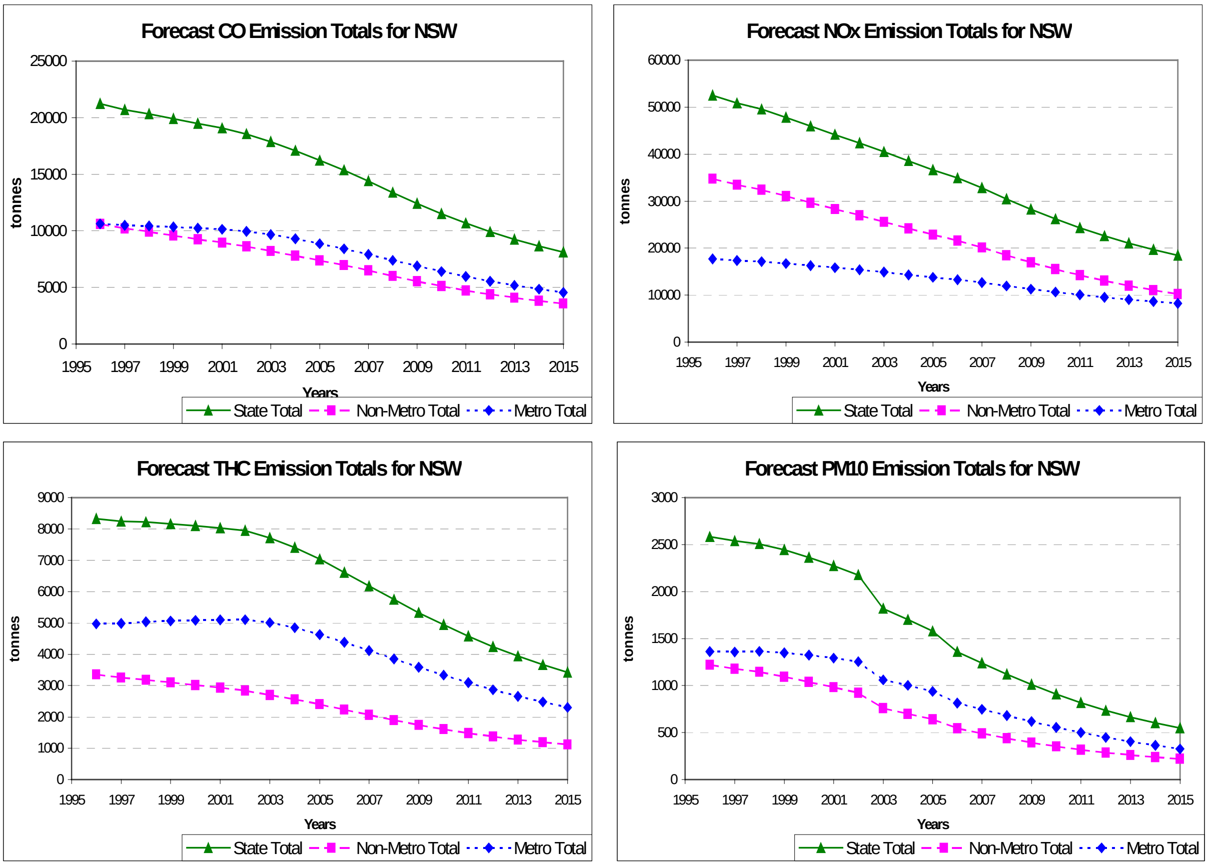
The results from Scenario III will be presented first, as these are what are projected to occur in the future under the proposed legislation for "Measures for a Better Environment", and then the differences between these Scenario III emissions and what would have occurred without changes to emission and fuel standards will be examined.

5.2 SCENARIO III EMISSION FORECASTS

The detailed Scenario III emission results for NSW in 1996 are given in **Table 5.1** so as to give some appreciation of the contribution of various vehicles operating on different functional road types and periods of the day.

Figure 5.1 shows that metropolitan emissions of CO, HC and PM10 are greater than in country regions but that NOx emissions are greater in rural areas because of the significantly greater NOx emissions at higher travel speeds in country regions. The sharp decrease in particulate emissions when both low and very low sulfur diesel fuel is introduced is also evident.

Figure 5.1: Scenario III Emissions for NSW, 1995 to 2015



The main feature of these figures is a decrease in the absolute level of all pollutants despite the increased travel demand of most vehicle types and the increasing percentage of diesel vehicles to total vehicle numbers in several vehicle types. This is the result of the better emission performance of younger vehicles and the turnover of older vehicles to younger vehicles in the fleet. Most emissions are seen to halve within 10 – 12 years but particulates halve in 8 years because of the introduction of lower sulfur diesel fuel. The total emissions for all other States for Scenario III are given graphically in **Figures 5.2 to 5.8.**

Table 5.1: Summary of NSW Pollutant Calculations for 1996, Scenario III

SUMMARY OF METROPOLITAN AND STATE EMISSIONS (tonnes) **NSW** **2015**

1. CO	2015-AM Peak			2015-Inter Peak			2015-PM Peak			2015-Evening			2015-Total	
	Fwy	Arterial	Local	Fwy	Arterial	Local	Fwy	Arterial	Local	Fwy	Arterial	Local	Fwy	Arterial
Cars	1.8	31.3	15.1	7.8	96.5	65.4	1.8	26.3	15.1	3.8	38.2	30.2	15.2	192.3
LCV's	3.6	62.8	30.3	15.7	193.8	131.3	3.5	52.9	30.3	7.7	76.7	60.6	30.5	386.2
Rigid Trucks	19.1	334.1	161.3	83.8	1031.5	699.0	18.8	281.4	161.3	40.8	408.4	322.6	162.5	2055.5
Articulated Trucks	6.3	109.5	52.8	27.5	337.9	229.0	6.2	92.2	52.8	13.4	133.8	105.7	53.2	673.4
Buses	3.2	56.0	27.0	14.0	172.8	117.1	3.1	47.1	27.0	6.8	68.4	54.0	27.2	344.3
Totals	**33.9**	**593.6**	**286.6**	**148.9**	**1832.5**	**1241.9**	**33.4**	**500.0**	**286.6**	**72.4**	**725.5**	**573.2**	**288.6**	**3651.7**

2. NOx	2015-AM Peak			2015-Inter Peak			2015-PM Peak			2015-Evening			2015-Total	
	Fwy	Arterial	Local	Fwy	Arterial	Local	Fwy	Arterial	Local	Fwy	Arterial	Local	Fwy	Arterial
Cars	2.1	20.1	9.8	11.5	79.3	42.5	2.4	19.0	9.8	5.9	36.2	19.6	21.9	154.7
LCV's	6.8	66.8	32.6	38.1	263.0	141.1	8.0	63.1	32.6	19.7	120.1	65.1	72.7	513.1
Rigid Trucks	33.2	325.0	158.5	185.7	1280.7	686.8	39.2	307.4	158.5	96.0	584.9	317.0	354.1	2498.0
Articulated Trucks	38.1	372.9	181.9	213.1	1469.6	788.1	45.0	352.7	181.9	110.2	671.2	363.8	406.3	2866.5
Buses	15.8	154.9	75.5	88.5	610.3	327.3	18.7	146.5	75.5	45.7	278.7	151.1	168.7	1190.3
Totals	**95.9**	**939.7**	**458.3**	**536.9**	**3703.0**	**1985.9**	**113.3**	**888.8**	**458.3**	**277.6**	**1691.2**	**916.5**	**1023.7**	**7222.6**

3. THC	2015-AM Peak			2015-Inter Peak			2015-PM Peak			2015-Evening			2015-Total	
	Fwy	Arterial	Local	Fwy	Arterial	Local	Fwy	Arterial	Local	Fwy	Arterial	Local	Fwy	Arterial
Cars	0.4	6.8	3.3	1.5	22.6	14.3	0.4	6.0	3.3	0.7	9.1	6.6	3.0	44.4
LCV's	0.9	14.7	7.1	3.3	48.7	30.8	0.8	12.9	7.1	1.5	19.6	14.2	6.5	95.8
Rigid Trucks	17.0	281.2	136.3	64.0	933.6	590.6	15.2	246.8	136.3	29.0	374.6	272.6	125.1	1836.2
Articulated Trucks	1.6	27.0	13.1	6.1	89.6	56.7	1.5	23.7	13.1	2.8	35.9	26.2	12.0	176.2
Buses	2.7	45.1	21.9	10.3	149.8	94.8	2.4	39.6	21.9	4.7	60.1	43.7	20.1	294.6
Totals	**22.7**	**374.7**	**181.6**	**85.3**	**1244.3**	**787.1**	**20.2**	**329.0**	**181.6**	**38.6**	**499.3**	**363.3**	**166.8**	**2447.3**

4. PM10	2015-AM Peak			2015-Inter Peak			2015-PM Peak			2015-Evening			2015-Total	
	Fwy	Arterial	Local	Fwy	Arterial	Local	Fwy	Arterial	Local	Fwy	Arterial	Local	Fwy	Arterial
Cars	0.3	4.5	2.2	1.0	15.0	9.5	0.2	4.0	2.2	0.5	6.0	4.4	2.0	29.4
LCV's	0.4	6.6	3.2	1.5	22.0	13.9	0.4	5.8	3.2	0.7	8.8	6.4	3.0	43.3
Rigid Trucks	2.0	32.3	15.6	7.3	107.1	67.8	1.7	28.3	15.6	3.3	43.0	31.3	14.4	210.7
Articulated Trucks	0.6	9.9	4.8	2.3	33.0	20.9	0.5	8.7	4.8	1.0	13.3	9.6	4.4	65.0
Buses	0.3	5.1	2.5	1.2	16.9	10.7	0.3	4.5	2.5	0.5	6.8	4.9	2.3	33.3
Totals	**3.5**	**58.4**	**28.3**	**13.3**	**194.0**	**122.7**	**3.2**	**51.3**	**28.3**	**6.0**	**77.9**	**56.7**	**26.0**	**381.6**

Figure 5.2: Scenario III Emissions for Victoria, 1995 to 2015

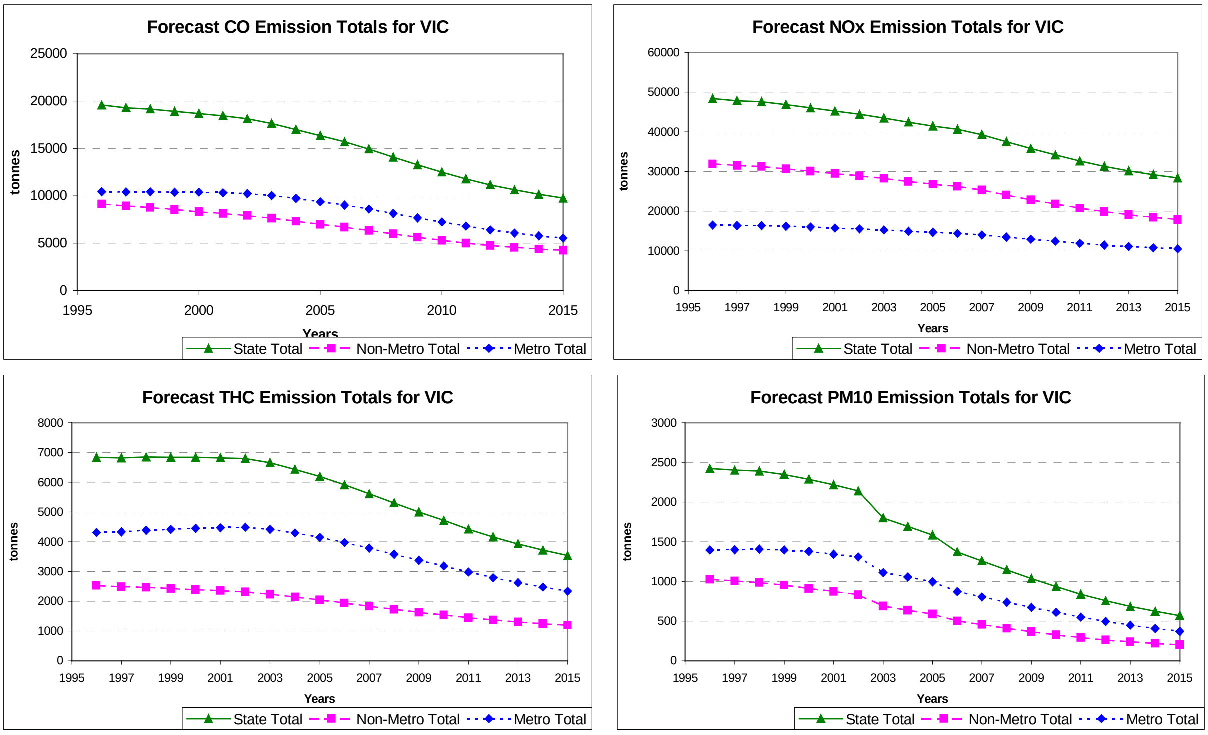


Figure 5.3: Scenario III Emissions for Queensland, 1995 to 2015

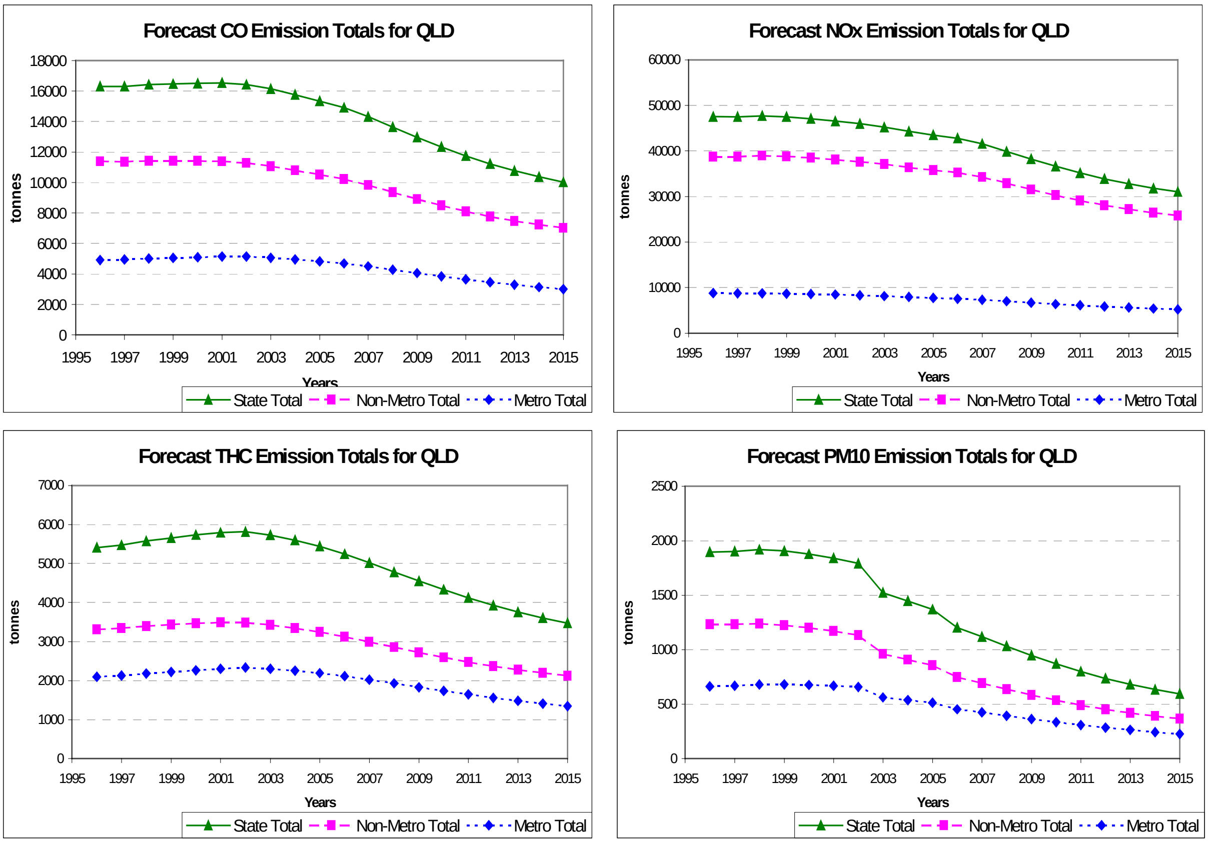


Figure 5.4: Scenario III Emissions for WA, 1995 to 2015

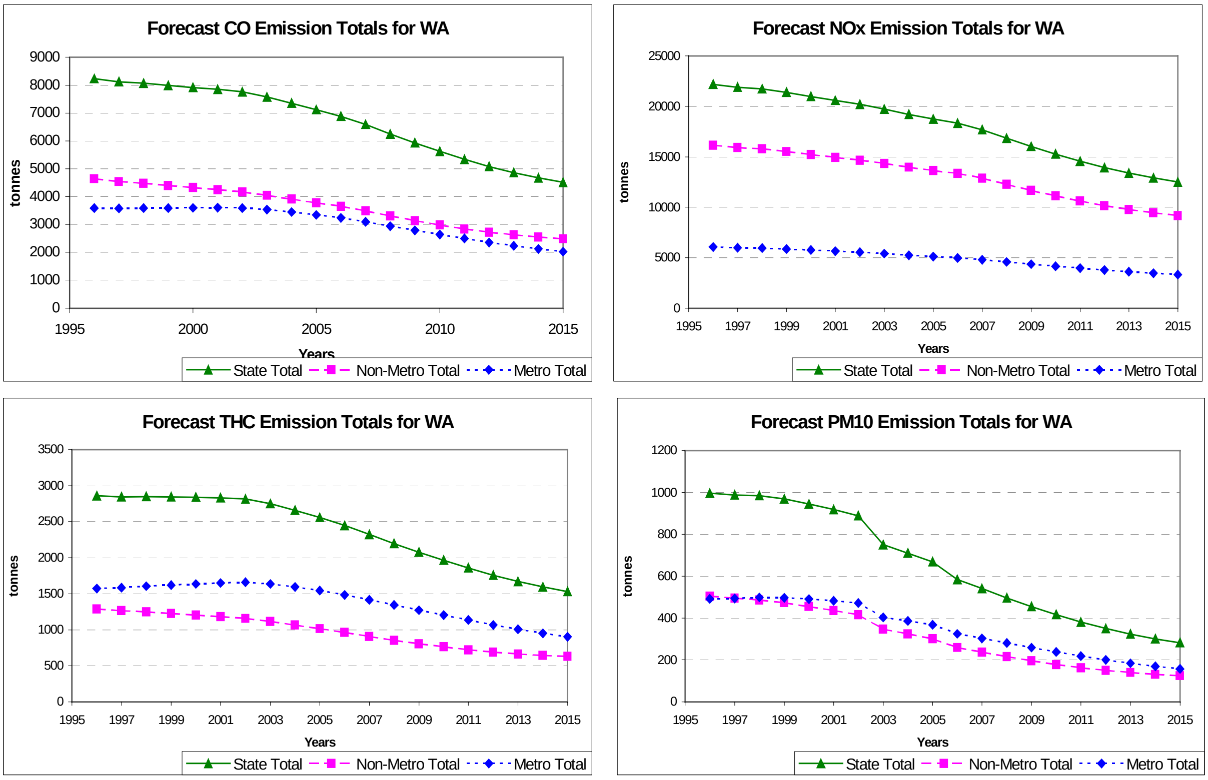


Figure 5.5: Scenario III Emissions for SA, 1995 to 2015

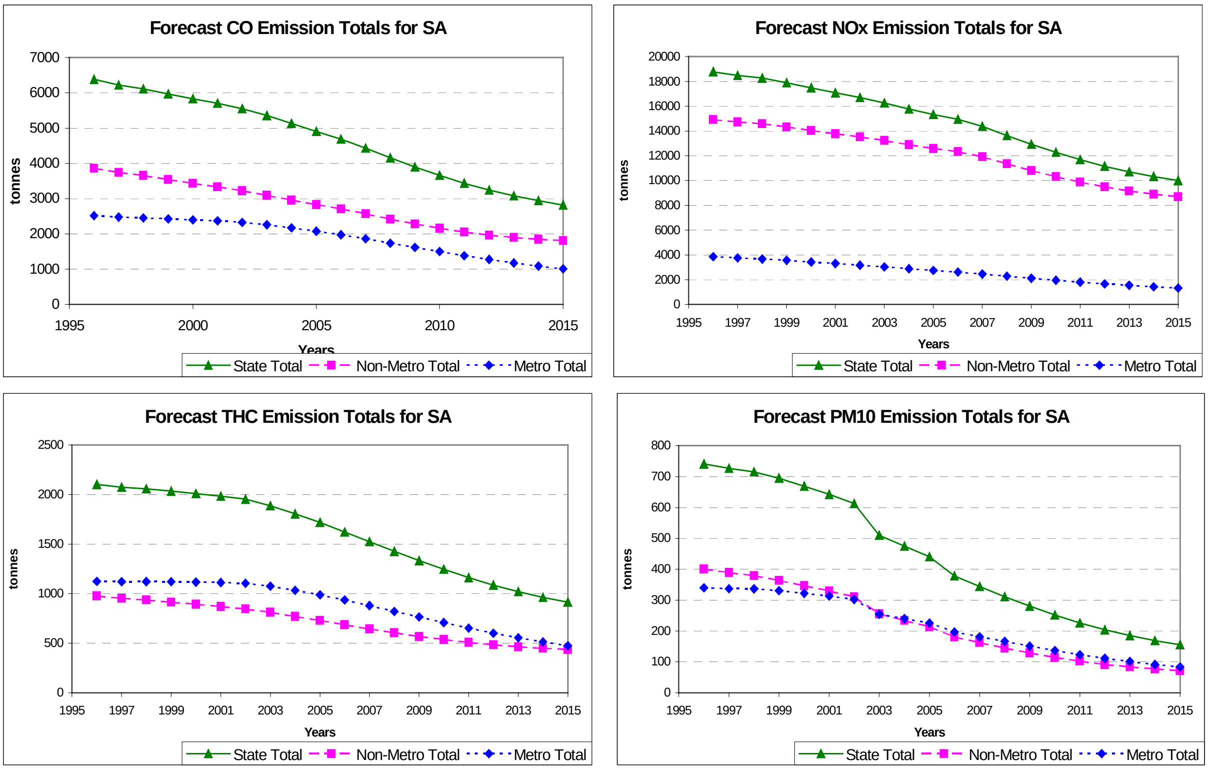


Figure 5.6: Scenario III Emissions for Tasmania, 1995 to 2015

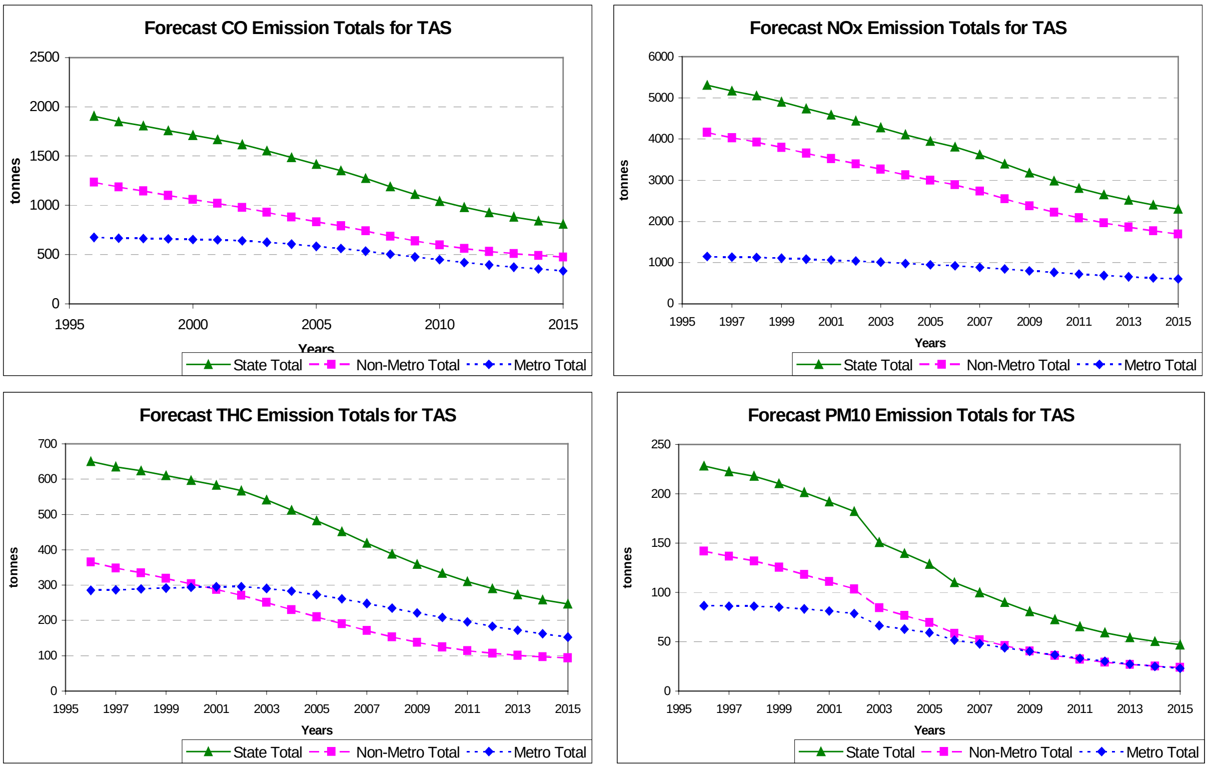


Figure 5.7: Scenario III Emissions for NT, 1995 to 2015

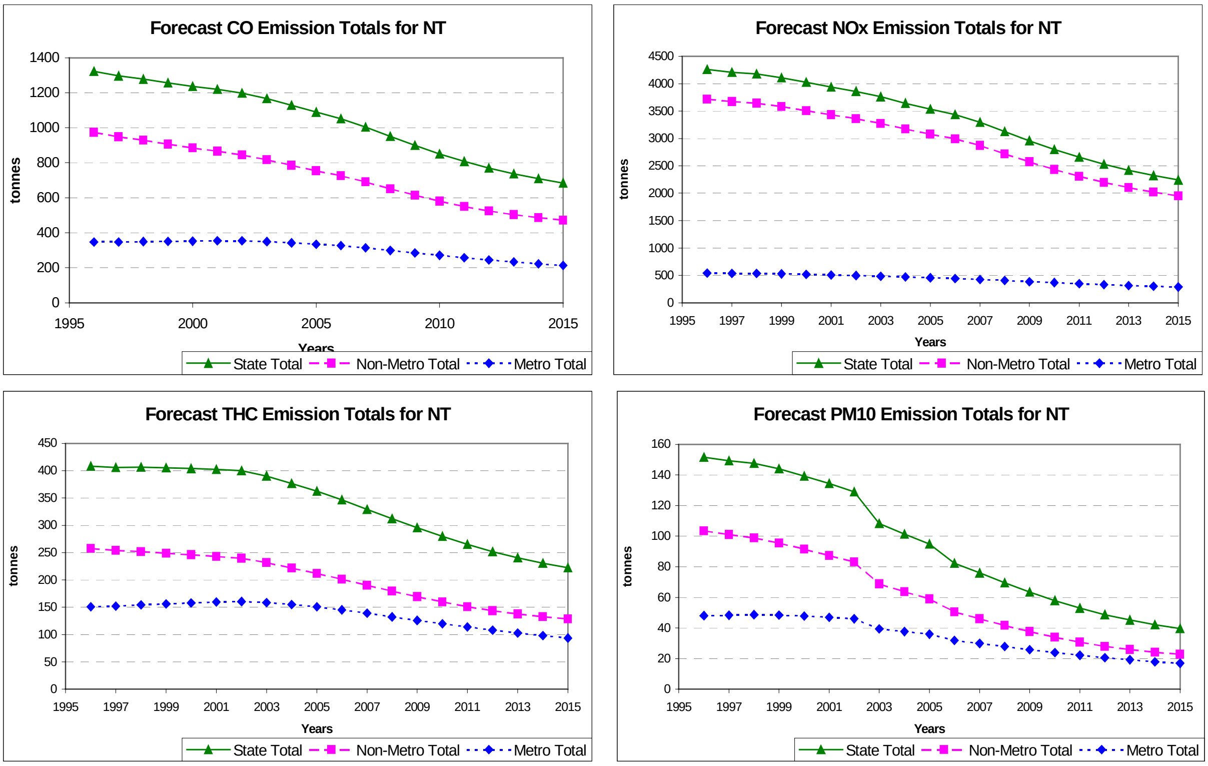
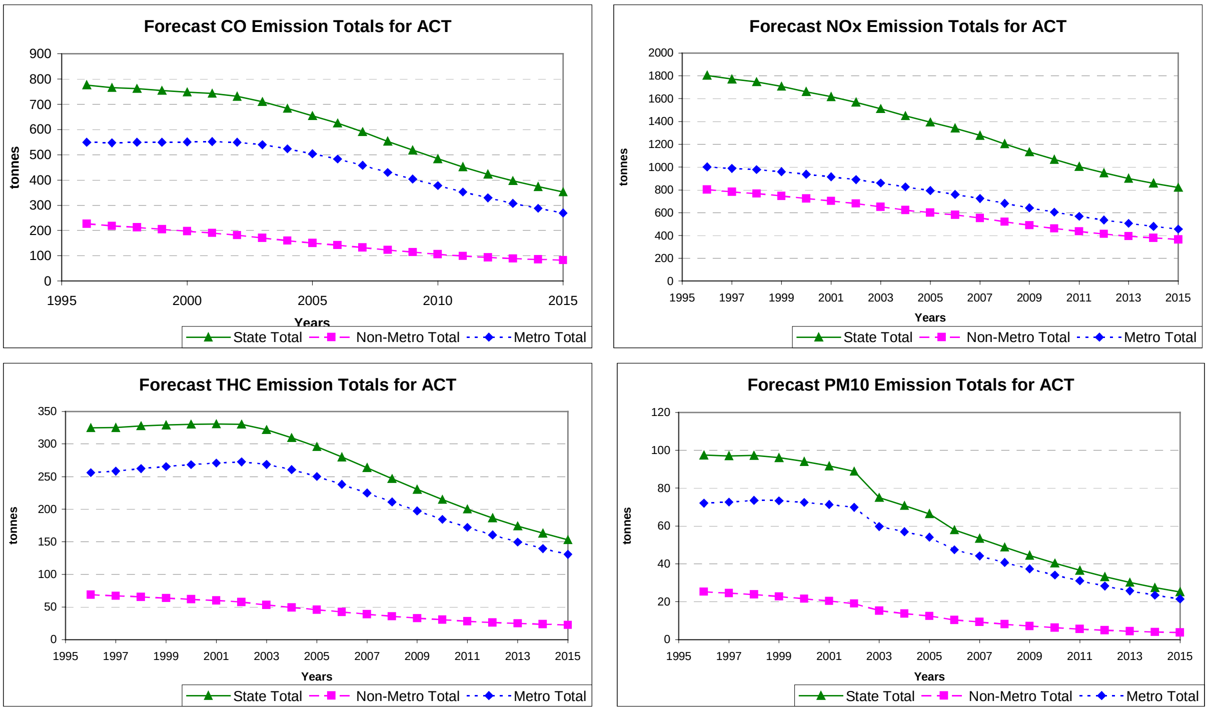


Figure 5.8: Scenario III Emissions for ACT, 1995 to 2015



The tabulation of detailed results by forecast years and State from 1995 to 2015 has not been included in the Appendices because of space considerations. Interested readers can inspect and print these values out themselves from the Excel spreadsheet model titled NEPC Scenario III.

It is necessary when interpreting trends in the above State emission results to acknowledge the changes to overall travel demand (greater increases in emerging States), changes in the vehicle mix (from rigid trucks to articulated trucks), the increase in the percentage of total vehicle travel by diesel vehicles (mainly in LCV's), the changing vehicle emission characteristics (such as the large historical and anticipated reductions in particulates from articulated trucks), the extent of the turnover in the vehicle fleet for each vehicle type (again highest in articulated trucks) and the variation of emissions with speed (generally decreasing with speed except for NOx which gives large increases with increasing speed, as in rural areas).

Some general results arising from these factors are as follows:

- a greater reduction in rural emissions than metropolitan emissions because of the greater use of articulated trucks in rural areas, the greater improvement in the emission performance characteristics of these vehicles and a more rapid turnover of older articulated trucks.
- a slower reduction in emissions in the younger States of Queensland and WA because of the higher increases in transport demand in these States

It should be noted that despite about 55% of total vehicle travel being in metropolitan areas there is a much lower percentage of diesel travel (9.84/27.68 = 36%) in Australian metropolitan areas (**Table 5.2)**. The figure is very similar (35%) for the NSW figures in **Table 5.3.**

Table 5.2: Estimated Travel by Diesel Vehicles in Australia in 1998 (million vehicle-km)

Vehicle Type	Metro Diesel Travel (Million vehicle-km)	Rural Diesel Travel (million vehicle-km)	Total Diesel Travel (million vehicle-km)
Passenger Vehicles	2.35	2.62	4.97
Light Commercial Vehicles	2.52	6.11	8.63
Rigid Trucks	3.21	3.02	6.23
Articulated Trucks	1.13	5.45	6.58
Buses	0.63	0.64	1.27
Totals	9.84	17.84	27.68

Source: Tables in this report

It is seen from the above table that the greatest difference in rural and metro travel characteristics occurs in the articulated truck vehicle category where only 17% of this vehicle's travel is in the metropolitan region (1.13/6.58). Articulated vehicles have a major influence on total NOx pollutant emissions as their emission rates can be 15 times that of other vehicles, especially at high speeds. Accordingly many of the rural States (Qld, WA, SA) have much higher NOx and other pollutant emissions in rural areas than metropolitan areas. This is less marked with particulates as PM emissions from articulated trucks are only 3 or 4 times as great as other vehicles. Earlier State emission charts (**Figures 5.1 to 5.8)** suggest that PM emissions in metropolitan and non-metro regions are therefore similar in magnitude.

Table 5.3: Estimated Travel by Diesel Vehicles in NSW in 1996 (million vehicle-km)

Vehicle Type	Metro Diesel Travel (Million vehicle-km)	Rural Diesel Travel (million vehicle-km)	Total Diesel Travel (million vehicle-km)
Passenger Vehicles	0.193	0.260	0.453
Light Commercial Vehicles	0.417	1.823	2.240
Rigid Trucks	1.094	0.940	2.034
Articulated Trucks	0.321	0.895	1.216
Buses	0.195	0.162	0.357
Totals	2.220	4.080	6.300

Source: Tables in this report

The percentage travel of diesel vehicle types in the NSW metropolitan area in **Table 5.3** can be compared to the percentage of total emissions by vehicle type (**Table 5.1)**. **Table 5.4** indicates that the metropolitan share of CO, HC and PM emissions is greater than the metropolitan travel share. This is due to the speed correction factor for these three pollutants being higher at the lower speeds encountered in metropolitan areas, thereby increasing metro emissions relative to rural travel. The reverse is the case for NOx where the metropolitan share of total NOx emissions is lower than the metropolitan travel share because this speed correction factor increases with speed and therefore gives greater relative emissions in rural areas.

Table 5.4: Estimated Metro Emissions by Diesel Vehicle Type in NSW in 1996 (% of Total State Emissions by Vehicle Type)

Vehicle Type	CO	NOx	HC	PM	% TRAVEL
Passenger Vehicles	51.8	35.7	55.7	55.7	42.6
Light Commercial Vehicles	24.9	14.6	28.0	27.9	18.6
Rigid Trucks	62.9	46.7	66.4	66.4	53.8
Articulated Trucks	34.2	21.1	37.8	37.8	26.3
Buses	63.6	47.4	67.2	67.2	54.6
Totals	50.0	33.7	59.7	59.7	35.2

Source: Tables in this report

The changes in annual metropolitan emissions from the diesel fleet for each capital city over the forecast period from 1996 to 2015 are shown in the following **Table 5.5**.

Significant reductions in emissions of 40 – 75% from the diesel vehicle fleet are projected over this period despite a significant growth in vehicle numbers and total annual distance travelled. The major reason for the decrease in all emissions is the better vehicle emission performance of the newer vehicles coming into the diesel fleet and the retirement of the older, poorly performing vehicles.

The bigger reductions in metro emissions in some States, like SA, are due to less State transport demand in such States, less demand in metropolitan areas relative to total State demand and the mix of existing vehicle types – there is a greater reduction in emission rates for rigid trucks so that any State with a higher percentage of freight being carried by rigid trucks in 1996 will see a greater reduction in emissions.

It should be remembered that emissions from diesel vehicles contribute about 2, 20, 4 and 73% respectively of the total emissions of CO, NOx, HC and PM (EPA 1998). Any reduction in CO and HC diesel emissions will not, therefore significantly affect the total emissions for these two pollutants, which will be influenced mainly by changes in the petrol vehicle fleet.
On the other hand, diesel emissions contribute the greatest percentage (73%) of particulate emissions and this study has found that particulates have the greatest percentage reduction of all pollutants between 1996 and 2015 (between 65 and 75%). The forecasts therefore indicate that there will be a significant reduction in overall emissions and ambient levels of particulates in Australian metropolitan areas.

Table 5.5: Projected Changes in Annual Metropolitan Fleet Emissions - 1995 to 2015, Scenario III

	EMISSION FORECASTS (TONNES)			
	CO	**NOX**	**THC**	**PM10**
ADELAIDE 1996	2522.1	3858.9	1124.5	340.4
ADELAIDE 2015	1009.4	1318.4	475.8	83.6
NET REDUCTION (%)	**60**	**66**	**58**	**75**
BRISBANE 1996	4915.4	8791.2	2097.1	662.5
BRISBANE 2015	3003.0	5212.4	1346.3	227.6
NET REDUCTION (%)	**39**	**41**	**36**	**66**
CANBERRA 1996	549.9	1001.9	255.9	72.1
CANBERRA 2015	270.0	455.3	130.7	21.4
NET REDUCTION (%)	**51**	**55**	**49**	**70**
DARWIN 1996	348.1	540.8	150.7	48.1
DARWIN 2015	213.2	289	93.7	16.9
NET REDUCTION (%)	**39**	**47**	**39**	**65**
HOBART 1996	673.1	1147.2	285.2	86.5
HOBART 2015	334.7	604.7	152.9	23.0
NET REDUCTION (%)	**40**	**47**	**46**	**73**
MELBOURNE 1996	10442.4	16487.7	4313.5	1396.1
MELBOURNE 2015	5513.8	10479.5	2335.9	369.1
NET REDUCTION (%)	**47**	**36**	**46**	**74**
PERTH 1996	3594.4	6058.8	1572.5	491.7
PERTH 2015	2027.2	3329.8	901.9	157.2
NET REDUCTION (%)	**44**	**45**	**43**	**68**
SYDNEY 1996	10622.4	17752.9	4975.5	1362.2
SYDNEY 2015	4548.0	8276.1	2306.9	327.7
NET REDUCTION (%)	**57**	**53**	**54**	**76**

The following two tables indicate what vehicle types are contributing to the total emissions of each pollutant for the State of NSW and for the metropolitan area only. The percentage contributions of each vehicle type in 1996 and 2015 are given so that any change can be identified.

Table 5.6: Contribution to Emissions by Vehicle Type, NSW, 1996 and 2015 (% of Total)

Vehicle Type	CO		NOx		HC		PM10	
	1996	2015	1996	2015	1996	2015	1996	2015
Passenger Vehcles	2.4	4.6	0.7	1.6	1.5	1.8	3.2	6.8
LCV's	11.0	18.3	6.6	13.2	5.8	7.2	14.9	18.8
Rigid Trucks	48.7	45.1	39.1	22.4	67.6	68.2	47.3	45.3
Artic. Trucks	29.5	22.6	42.3	47.8	15.5	9.6	27.0	20.4
Buses	8.3	9.4	11.3	15.0	9.6	13.3	7.5	8.7
Totals	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Tables in this report

It is evident that rigid trucks provide the major portion of all pollutants in NSW in both 1996 and 2015 except for NOx, where articulated trucks contribute the most. This is a little surprising for the year 2015 given the reduction in demand for this vehicle type over the period. Although there is a slight reduction in the contribution of rigid trucks, it is postulated that emissions remain high because of the high unit emissions of these vehicles until 2002 (see **Figures 2.13 and 2.17**) and the slow turnover of the rigid truck vehicle fleet. Despite a substantial increase in the travel demand for articulated trucks their contribution to total pollutant emissions decrease except for NOx. Both cars and LCV's increase their share of pollutants in 2015 because of increasing use of these diesel vehicle types.

Table 5.7: Contribution to Emissions by Vehicle Type, Metropolitan NSW, 1996 and 2015 (% of Total)

Vehicle Type	CO		NOx		HC		PM10	
	1996	2015	1996	2015	1996	2015	1996	2015
Cars	2.5	5.3	0.8	2.2	1.4	1.8	3.4	7.7
LCV's	5.5	10.6	2.8	7.1	2.7	3.9	7.9	11.4
Rigid Trucks	61.2	56.3	53.9	34.6	75.3	75.0	59.7	55.2
Artic. Trucks	20.2	18.4	26.5	39.7	9.8	7.2	19.4	17.0
Buses	10.6	9.4	15.9	16.5	10.8	12.1	9.6	8.7
Totals	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Tables in this report

The dominance of the rigid truck contribution to all pollutants in metropolitan NSW is even greater than for the State as a whole. Buses also increase their share of most pollutants. Metro trends between 1996 and 2015 are similar to the trends in NSW as a whole.

An estimate of the average emission rate for all vehicles in the Melbourne metropolitan area can be made by taking the total tonnage of diesel emissions for each pollutant for each vehicle type and dividing by the total diesel vehicle-km travelled by this vehicle type. These estimated average emission rates for each vehicle type are compared against the arterial road rates used in a recent emissions study (EPA 1998) in the Port Phillip region (Melbourne). This comparison is shown in **Table 5.8**.

Table 5.8: A Comparison of 1996 Average Vehicle Diesel Emission Rates in Melbourne from This Study with Values Used in the Port Phillip Region Air Emissions Inventory Study (EPA 1998)

	CARS	LCV'S	RIGID TRUCKS	ARTIC. TRUCKS	BUSES
CO					
- all vehicle average this study (1996)	1.41	1.41	5.95	6.71	5.76
- average Port Phillip Study	1.10	1.40	8.00	8.00	8.00
NOx					
- all vehicle average this study (1996)	0.74	1.24	8.94	15.00	14.74
- average Port Phillip Study	1.10	1.40	8.80	8.80	8.80
HC					
- all vehicle average this study (1996)	0.35	0.32	3.41	1.52	2.73
- average Port Phillip Study	0.50	0.80	1.50	1.50	1.50
PM10					
- all vehicle average this study (1996)	0.24	0.26	0.74	0.82	0.66
- average Port Phillip study	0.19	0.26	2.09	2.09	2.09

Note: Heavy duty diesel emission rates in EPA (1998) for the Port Phillip study are assumed to apply to rigid trucks, articulated trucks and buses.

The average emission values show general agreement but there are some variations, such as:

- the lower particulate values for rigid trucks, articulated trucks and buses in this NEPC study compared to the Victorian study;
- the higher NOx values for articulated trucks and buses assumed in this NEPC study compared to the Victorian study;
- the higher HC values for rigid trucks in this NEPC study compared to the Victorian study.

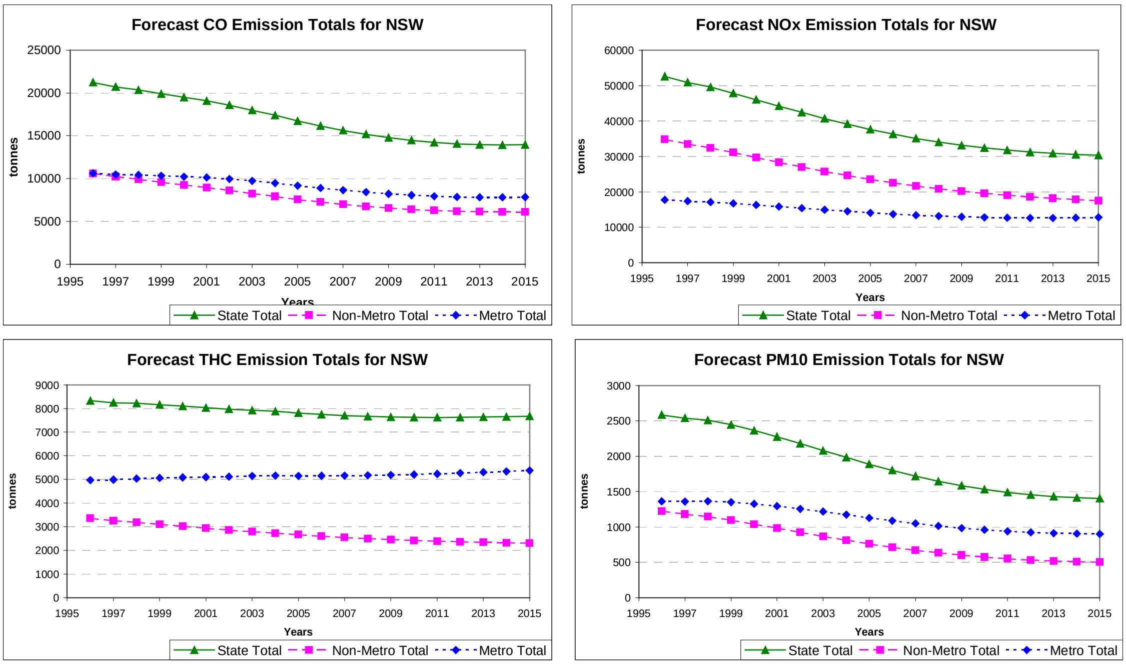
The general agreement between the two studies provides some confidence that the results from this study will give comparable results to previous diesel emission studies.

Further detailed results for this Scenario III analysis for all States and all forecast years can be found in the Excel spreadsheet title NEPC Scenario III.

5.3 ALTERNATIVE EMISSION SCENARIOS

The emission projections under Scenario I for NSW are given in graphical form in **Figure 5.9.** There is generally a reduction in emissions over the forecast period but HC emissions increase in metropolitan areas and there is less reduction in other pollutants in metro areas.

Figure 5.9: NSW Emissions, 1995 to 2015, for Scenario I; No Change in Emission Standards or Diesel Fuel to 2015



The emission forecasts under Scenario II which assumes the introduction of lower sulfur fuel shows no change in CO, NOx and HC emissions but is seen to reduce PM emissions relative to Scenario I, as shown in **Figure 5.10** following. The drop in particulates in 2003 after the lower sulfur fuel is introduced is evident in the particulate emission graph.

A comparison of emissions for all four pollutants over the forecast period for metro NSW for all three scenarios is given in Figure 5.11. There is no difference in the emissions for CO, NOx and HC between Scenarios I and II but appreciable reductions of all these pollutants from the introduction in Scenario III of Euro II through Euro IV standards and lower sulfur diesel fuel. There is also a difference in particulate emissions between Scenarios I and II because of the lower sulfur fuel in Scenario II.

The percentage differences between Scenario III and Scenario I in the pollutant emissions from diesel vehicles in NSW in the year 2015 are given in Table 5.4.

Figure 5.10: NSW Emissions, 1995 to 2015, for Scenario II

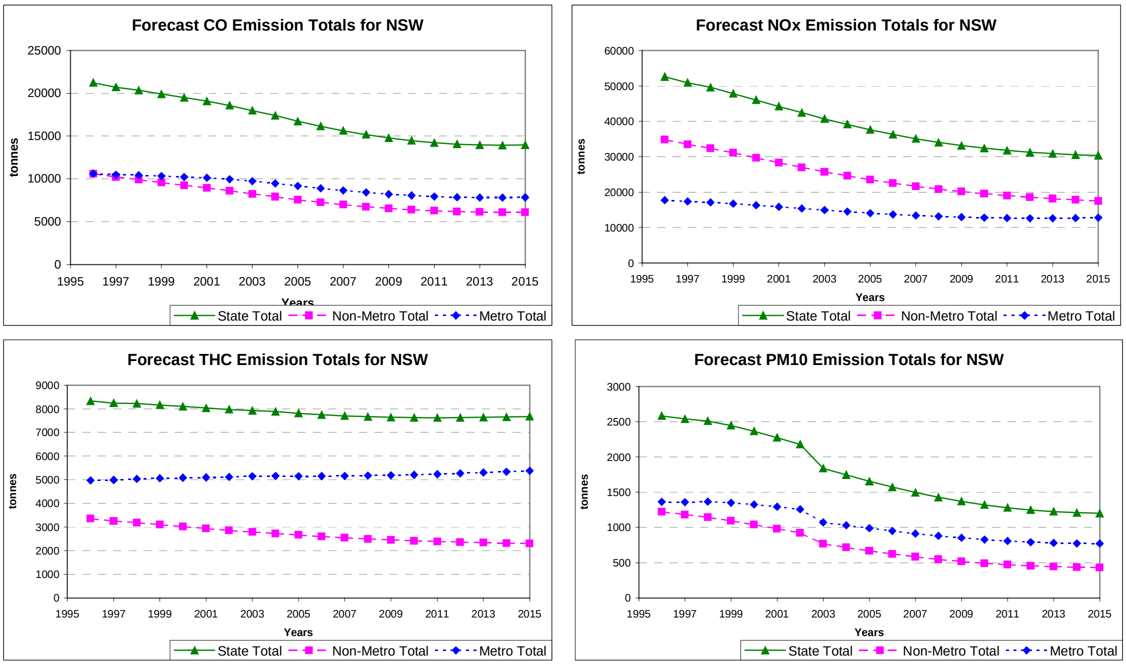
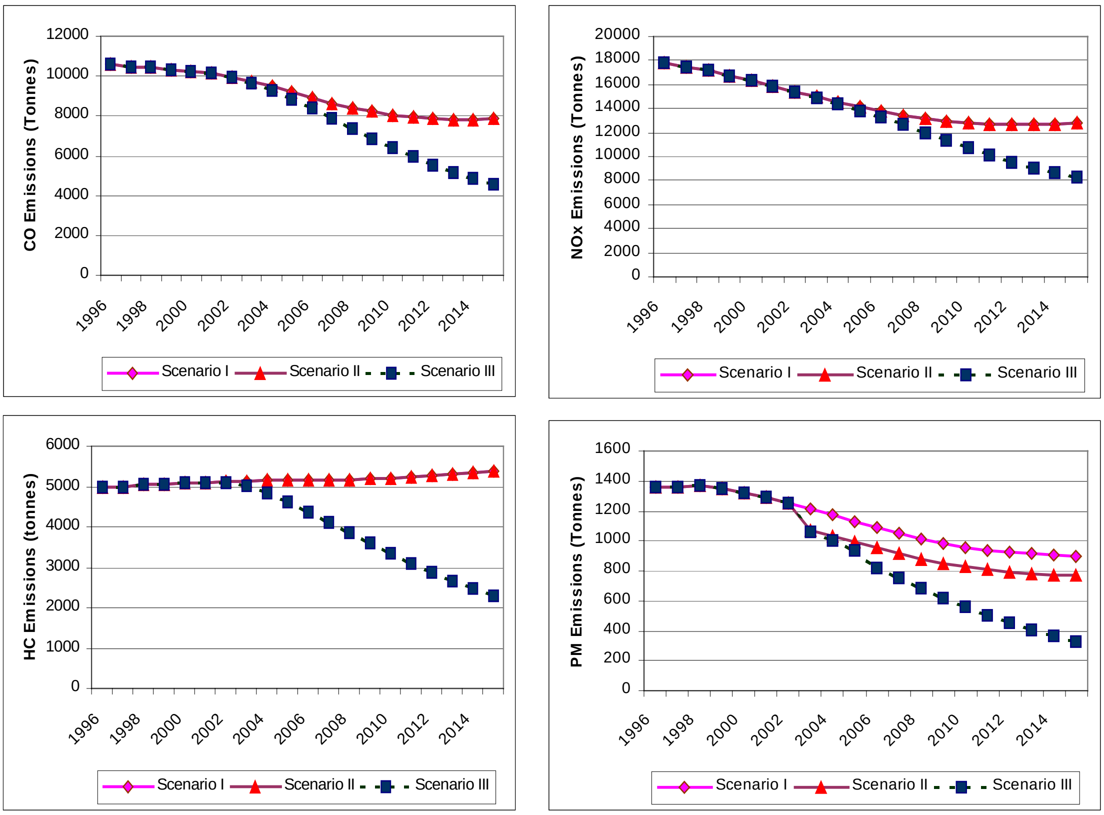


Figure 5.11: NSW Metropolitan Emissions for Different Scenarios, 1996 to 2015



Note:	Scenario I:	No improvement in emission or diesel fuel standards after 2002
	Scenario II:	Improvement in diesel fuel standards only
	Scenario III:	Improvement in diesel fuel and emission standards as per “Measures for a Better Environment”

The actual values for the emissions from all diesel vehicles in the metro areas of all States in the year 2015 for the various scenarios are given in Table 5.9. As for the figures comparing the various scenarios, the introduction of the emission and fuel standards in the tax reform package (Scenario III) is seen to significantly reduce all metropolitan emissions in 2015 compared to Scenarios I and II. The table also indicates that the introduction of low sulfur fuels will not affect the projections for CO, NOx and HC but will significantly reduce PM emissions, as shown by the difference between the values for Scenarios I and II in the last column of this table.

Table 5.9: Alternative Emission Scenarios in Metropolitan Areas, 2015 (tonnes)

	EMISSION FORECASTS (TONNES)			
	CO	NOX	THC	PM10
ADELAIDE				
SCENARIO I	1939	2148	1140	225
SCENARIO II	1939	2148	1140	184
SCENARIO III	**1009**	**1318**	**476**	**84**
BRISBANE				
SCENARIO I	5234	8312	3003	664
SCENARIO II	5234	8312	3003	490
SCENARIO III	**3003**	**5212**	**1346**	**228**
CANBERRA				
SCENARIO I	515	731	317	61
SCENARIO II	515	731	317	49
SCENARIO III	**270**	**455**	**131**	**21**
DARWIN				
SCENARIO I	377	480	209	45
SCENARIO II	377	480	209	34
SCENARIO III	**213**	**289**	**94**	**17**
HOBART				
SCENARIO I	565	972	347	74
SCENARIO II	565	972	347	50
SCENARIO III	**335**	**605**	**153**	**23**
MELBOURNE				
SCENARIO I	9756	11828	5268	1326
SCENARIO II	9756	11828	5268	874
SCENARIO III	**5514**	**10480**	**2336**	**369**
PERTH				
SCENARIO I	3748	5410	2080	470
SCENARIO II	3748	5410	2080	351
SCENARIO III	**2027**	**3330**	**902**	**157**
SYDNEY				
SCENARIO I	7845	12803	5376	1087
SCENARIO II	7845	12803	5376	770
SCENARIO III	**4548**	**8276**	**2307**	**328**

Note: Scenario I: No improvement in emission or diesel fuel standards after 2002

Scenario II: Improvement in diesel fuel standards only

Scenario III: Improvement in diesel fuel and emission standards as per "Measures for a Better Environment"

Further detailed results for all States and all years for Scenario I can be found in the Excel spreadsheet NEPC Scenario I. Further detailed results for all States and all years for Scenario II can be found in the Excel spreadsheet NEPC Scenario II.

5.4 THE EFFECT OF ENGINE MAINTENANCE

Although an allowance for the Mobile 5 emissions deterioration factor was included in the spreadsheet model this parameter was set to zero for all forecasts as the emission rates provided were the best estimate of actual emissions and included engine deterioration and maintenance factors.

Actual in service tests on European petrol and diesel cars showed much less engine deterioration for diesel engines compared to petrol engines (Houghton 1994).

However, in service tests on diesel vehicles described in Faiz et al 1996 have shown that inadequate maintenance or tampering with diesel engines can increase hydrocarbons and particulates in particular and that these increases are generally evident in the older vehicles. These increased emissions are not spread over the whole fleet as 20% of poorly maintained diesel vehicles were responsible for 80% of these increased emissions (this was also shown to be the case from in service emission testing of cars in Australia (FORS 1996).

The in service vehicle emission study in Australia found that tuning and maintenance of petrol cars could reduce CO emissions by 25%, HC emissions by 16% and NOx emissions by 9% (FORS 1996). These figures are similar to actual I/M programs for petrol engines in British Columbia which resulted in reductions of 24% for CO, 20% for HC and 1% for NOx (Faiz et al 1996, Box 4.2).

I/M programs for diesel vehicles focus on testing the black smoke from exhausts but these tests do not record the non-black particulates. The primary cause of excess smoke emissions are incorrect air-fuel ratio control settings, incorrect fuel injection timing and dirty air filters, many of which are tampered with to obtain more power from the engine. The nature of the increased emissions from diesel engines is different from petrol engines and is focused upon greater hydrocarbon and particulate emissions. For example, it was estimated that 42% of HC, 56% of PM10 and 6% of NOx emissions from heavy vehicle duty vehicles in California resulted from engine tampering (Faiz et al 1996, p.135). Most of these increases come from the older rigid trucks, buses and articulated trucks.

Another study in France on light duty diesel vehicles found an average reduction of 22% in HC, 25% in particulates, 3% in CO and an increase of 5% in NOx (Faiz et al 1996, Table 4.15). Lower emission reductions are also forecast for I/M programs for heavy vehicles in the US (5 – 15% for HC) (Faiz et al 1996, Table 4.13).

These studies indicate that significant reductions in pollutants from I/M programs for diesel engines will be confined mainly to HC and PM10 emissions. The average reduction in HC and PM emissions are similar to the average HC reduction in petrol engines and of the order of 10 – 20%.

This percentage reduction can be used as a first approximation of the benefits of an I/M program and of the deterioration in emissions performance with age. All estimates of pollutant emissions for HC and PM in the various Scenarios for the various years could therefore be lower by 10 to 20% assuming no deterioration in emissions, or the introduction of an extensive inspection and maintenance program. Greater accuracy in this estimation of engine maintenance effects is not considered to be realistic given the initial estimation of emission rates and the paucity of data on the effects of maintenance programs on different vehicle types at their various vehicle ages.

6. CONCLUSIONS

The forecasts of travel and emissions from diesel vehicles given in this report are the result of developmental work to model travel demand in various States and regions by vehicle type and then to apply a distribution of travel and emission characteristics to different vehicle ages of each vehicle type.

This model is more detailed than those generally used in emission inventory work in Australia as it provides different vehicle emission characteristics for each vehicle age, takes into account the country of origin of the various vehicle types and separately estimates emissions on three different functional road types and four daily periods in metropolitan areas where emissions are greatly influenced by vehicle speeds. The model also calculates emissions for both metropolitan and rural areas in each State.

The emission values from the model have been calibrated against the values used in the Port Phillip air emissions inventory and general agreement occurs, except in the values of particulate and NOx emissions for heavy vehicles and hydrocarbons for rigid trucks.

Assumptions have been made at various points in this modelling work and may have to be changed in the light of more recent data that is being collected under other NEPC studies. All of these assumptions have been placed transparently at the beginning of each spreadsheet in the model so that future technical developments can be incorporated in the modelling process.

The forecasts for alternative Scenario III, which model the effects of the new emission and diesel fuel standards arising from the ANTS II tax reform package, indicate an appreciable reduction in all pollutant emissions from diesel vehicles, despite a significant increase in LCV and articulated truck travel demand from the service and freight industries respectively.

A comparison of this scenario with alternative scenarios existing before these new standards were introduced has shown reductions in all emissions with the greatest decline in particulate emissions and the least reduction in NOx emissions.

The Port Phillip metropolitan region emission study (EPA 1998) found that the emissions from diesel vehicles contributed 2, 20, 4 and 73% to the total emissions of CO, NOx, HC and PM respectively. Any reduction in CO and HC diesel emissions will not, therefore significantly affect the total emissions for these two pollutants, which will be influenced mainly by changes in the petrol vehicle fleet.

The study has concluded that changes to the diesel vehicle fleet and emission standards will bring about the greatest percentage reduction in particulates. Not only are particulate levels reduced the most but diesel emissions contribute the greatest percentage (73%) of this particular pollutant. The study therefore indicates that overall particulate emissions and levels in Australian metropolitan areas should fall significantly.