Emissions Estimation Technique Manual

for

Aggregated Emissions from Motor Vehicles

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EMISSIONS ESTIMATION TECHNIQUE MANUAL: AGGREGATED EMISSIONS FROM MOTOR VEHICLES

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AGGREGATED EMISSIONS FROM MOTOR VEHICLES**

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1.0 Introduction

1.1 The NPI

The National Pollutant Inventory (NPI) was established under a National Environment Protection Measure (NEPM) made by the National Environment Protection Council (NEPC) under Commonwealth, State and Territory legislation on 27 February 1998. This Measure is to be implemented progressively through the laws and administrative arrangements of each of these participating jurisdictions (i.e. State and Territory Governments).

The NEPM and an associated Memorandum of Understanding for the NPI, which have been published as a single document by the NEPC, provide more details on the purpose and structure of the NPI, and the arrangements for implementation of the NEPM that have been agreed by the jurisdictions. Users of this Manual should read this publication if they are unfamiliar with the NEPM or the NPI.

1.2 Purpose and Scope of the Manual

The NPI will be developed as an internet database designed to provide information on the types and amounts of certain chemical substances being emitted to the air, land and water environments. If the NPI is to achieve its aim of communicating useful and reliable information to the community, industry and governments on pollutants present in our environment, the emissions estimation techniques (EETs) used to generate inputs to the NPI need to be consistent, and the process for developing these techniques needs to be transparent. This Manual has been developed, reviewed and finalised in this context.

The NEPM contains a list of substances for which emissions will be reported on an annual basis to the Commonwealth Government, which will then compile and publish the NPI. The aggregated emissions manuals, of which this is one, have been prepared to assist State and Territory Governments in preparing these submissions, and to facilitate consistent reporting between these jurisdictions.

State and Territory Governments will also be compiling and submitting emissions data based on annual inputs from reporting facilities. These facilities are primarily industrial enterprises which use (or handle, manufacture or process) more than specified amounts of certain polluting substances, burn more than specified amounts of fuel, or consume more than certain amounts of energy. These amounts or “thresholds” (which are clearly defined in the NEPM) govern whether an industrial facility is required to report and what substances it is required to report on, and industry handbooks are being developed to help industries to prepare the information for these reports.

The aggregated emissions manuals complement these handbooks, and are intended to enable Governments to estimate emissions from non-industrial activities (e.g. transportation, domestic and commercial activities) and emissions from industry which are not reported because the relevant thresholds are not exceeded or are exempt from reporting.

Annual submissions are also to be prepared and submitted in conformance with the NPI Data Model and Data Transfer Protocol. For emissions to the air environment, this Protocol only requires jurisdictions to submit data on emissions into the particular airsheds that are listed in the Protocol, and not to the rest of each jurisdictional area. For example, under the 1998 to 2000 Memorandum of Understanding, in Victoria, emissions data are only required for the Port Phillip and Latrobe Valley Regions. In addition, emissions data are required to be submitted on a gridded basis, with each jurisdiction determining a grid domain and grid cell size necessary to meet its obligations under Section 7 of the NEPM.

Therefore, in addition to recommending and providing details and examples of appropriate emissions estimation techniques (EETs) for the relevant NPI substances, this Manual provides guidance on the spatial allocation of emissions and the use of area-based surrogates for accurately distributing the activities or sources in question.

1.3 Application of the Manual

Each of the aggregated emissions manuals provides details of:

- the NPI substances that are expected to be emitted from the relevant aggregated source type;
- the origins or sources of the emissions, and the processes that may generate them;
- the impacts of any control equipment or procedures on those emissions;
- the broad approaches that may be employed in the estimation and spatial allocation of emissions;
- details of emission factors to be used in the estimation of emissions; and
- a series of illustrative sample calculations for each estimation technique.

Each of the manuals also contains a section on “Uncertainty Analysis”, which provides information and guidance to users on the reliability of the various estimation techniques, problems and issues associated with their development and application, and recommendations for their improvement. In preparing the aggregated emissions manuals it has been recognised that some jurisdictions already undertake detailed emissions inventories on a regular basis, based on relatively sophisticated methodologies. For these jurisdictions the manuals offer techniques which represent commonly available best practice for emissions estimation in Australia (i.e. techniques of high quality which can be employed by larger or more experienced jurisdictions with an acceptable expenditure of time and effort). The most recent developments in inventory methodology in Australia and overseas have been considered in selecting and documenting these techniques.

Where a more simplified methodology for emissions estimation of acceptable quality is available, it is recommended in the manual for the use of those jurisdictions which may, for the time being at least, lack the data, resources or expertise to employ a more sophisticated approach, or not see the need for highly reliable estimates in that particular part of the inventory.

2.0 Emissions Covered by the Manual

2.1 NPI Substances

Table 1 lists the NPI substances that are typically emitted from motor vehicles.

Table 1: NPI Substances Emitted from Motor Vehicles [a]

Acetaldehyde	n-Hexane
Acetone	Lead and compounds
Benzene	Manganese and compounds
1,3-Butadiene	Nickel and compounds
Cadmium and compounds	Oxides of nitrogen
Carbon monoxide	Particulate matter ≤ 10 μm (PM_{10})
Cyclohexane	Polycyclic aromatic hydrocarbons (PAH)
Chromium (III) compounds	Styrene
Chromium (VI) compounds	Sulphur dioxide
Cobalt and compounds	Toluene
Copper and compounds	Total volatile organic compounds (VOCs)
Ethylbenzene	Xylenes
Formaldehyde	Zinc and compounds

[a] Paragraph 2 (e) of Schedule A to the NEPM requires that, for the purposes of emissions estimation, a substance listed in Tables 1 and 2 of that Schedule as "(a metal) and a compound" refers only to the amount of metal that may be emitted. The EETs described in this manual have been prepared accordingly. Thus, the emission factors for metals and their compounds relate only to the amount of the metal itself that may be emitted as a part of these compounds.

2.2 Emission Sources and Related Processes

A motor vehicle, for the purposes of this manual, is defined as an on-road vehicle that derives some, or part of, its power for propulsion from the combustion of fossil fuel. "On-road vehicles" essentially include all vehicles that are intended for on-road use (including recreational four-wheel drive vehicles that may also be used off roads), but do not include vehicles designed exclusively for off-road use (e.g. construction vehicles).

The energy to propel the vehicle comes from burning fuel in an engine. Pollution from vehicles arises from the by-products of the combustion process (emitted via the exhaust system) and from evaporation of the fuel itself. Particulate matter is also emitted from brakes and tyre wear.

Various types of pollutants are produced in the combustion process. A range of volatile organic compounds (VOCs) are produced because the fuel is not completely burnt (oxidised) during combustion. Oxides of nitrogen (NO_x) result from the oxidation of nitrogen at high temperature and pressure in the combustion chamber. Carbon monoxide (CO) occurs when carbon in the fuel is partially oxidised rather than fully oxidised to carbon dioxide. Sulphur dioxide (SO_2) and lead are derived from the sulphur and lead in fuels. Particulate matter is produced from the incomplete combustion of fuels, additives in fuels and lubricants, and worn material that accumulates in the engine lubricant. These additives and worn materials also contain trace amounts of various metals and their compounds which may be released as exhaust emissions.

Evaporative emissions come mainly from petrol (diesel fuel has a much lower vapour pressure) and consist of VOCs and small amounts of lead. These emissions may occur in several ways:

Diurnal Losses: As the ambient air temperature rises during the day, the temperature of fuel in the vehicle's fuel system increases and increased vapour is produced.

Running Losses: Heat from the engine and exhaust system can vaporise gasoline when the car is running.

Hot Soak Losses: Because the engine and exhaust system remain hot for a period of time after the engine is turned off, gasoline evaporation continues when a car is parked.

Resting Losses: Vapour may be lost from the fuel system or the evaporative emission control system as a result of permeation through rubber components and other leaks.

Another source of emission is the crankcase of early model (pre-1970) vehicles without positive crankcase ventilation systems. In such vehicles, losses occur directly from venting of the crankcase during engine operation.

Evaporative emissions also occur from vehicle refuelling at service stations or from fuel tanker loading and unloading. These emissions can be estimated using the EET Manual for Aggregated Emissions from Service Stations, or will be estimated by reporting facilities as part of NPI reporting arrangements, and are not considered in this manual. Emissions can occur when liquid fuel leaks or is spilt, but these emissions are also not considered in this manual.

Another type of emission that arises from use of motor vehicles is dust emissions from roads. These emissions are covered in the EET Manual for Aggregated Emissions from Paved and Unpaved Roads and will also not be considered in this manual.

Finally, emissions from off-road vehicles, such as trail bikes, are also not covered in this manual.

2.3 Emission Controls and Other Factors Affecting Emissions

2.3.1 Vehicle Emission Standards

Australian Design Rules (ADRs) are mandatory standards for motor vehicle safety and emissions which are made under the Commonwealth's Motor Vehicle Standards Act 1989. They apply to all vehicles prior to first registration in Australia, and are administered by the Commonwealth Department of Transport and Regional Services. Requirements for in-service vehicles may be subject to State regulation.

Exhaust and evaporative emissions from new petrol-fuelled passenger vehicles and light commercial vehicles up to 2.7 tonnes Gross Vehicle Mass (GVM) are currently regulated by ADR 37/01. This Rule was based on standards applying in the USA for the 1981 and 1982 model years, and was applied in Australia during 1997 and 1998. A summary of the principal ADRs for control of emissions of light duty petrol-fuelled vehicles is presented in Table 2.

Table 2: ADR Emission Standards for Light Duty Petrol Vehicles

Standard	Year of Application	Equivalence	Exhaust Emission Limits (g km^{-1})			Evaporative Emission Limit (g $test^{-1}$)
			CO	HC	NO_x	HC
ADR 27A	1976	US 1973	24.2	2.1	1.9	2 [b]
ADR 27B	1978		22	1.9	1.9	6 [c]
ADR 27C [a]	1981		18.6	1.75	1.9	2 [c]
ADR 37/00	1986	US 1975	9.3	0.93	1.93	2 [c]
ADR 37/01	1997-99	US 1981	2.1	0.26	0.63	2 [c]

[a] Applied in NSW only.
[b] As measured by the canister test.
[c] As measured by the more rigorous SHED (Sealed Housing for Evaporative Determination) test.

ADR 36/00 applies long-superseded US emission standards to petrol engines used in heavy duty vehicles greater than 2.7 tonnes GVM. Since there are very few of these vehicles in Australia, this ADR no longer has much significance.

ADR 70/00, which was implemented in 1995/96, sets emission limits for diesel engines used in heavy duty vehicles. It provides manufacturers with the option of complying with one of three sets of emission standards, being those then current in Europe (Euro 1), USA (1991) and Japan (1993/94). This ADR is based on engine dynamometer testing procedures, which are different in each country. As an indication only, the ADR 70/00 limits (expressed as Euro 1) are shown in Table 3.

Table 3: Emission Standards for Heavy Duty Diesel Vehicles

Standard	Years of Application	Exhaust Emission Limits (g kW^{-1} hr^{-1})			
		CO	HC	NO_x	TSP
ADR 70/00 (Euro 1)	1995-96	4.5	1.1	8.0	0.36

ADR 30/00 was introduced in 1976 and sets visible smoke emission standards for diesel vehicle engines. It is consistent with European and US standards of the early 1970's.

2.3.2 Vehicle Emission Controls

Exhaust emissions from petrol-engined vehicles of more recent design (e.g. all passenger cars manufactured from 1986) are primarily controlled by catalytic converters. These catalysts convert hydrocarbons (HC) and carbon monoxide (CO) to carbon dioxide and water, and (in the case of three-way converters) reduce nitrogen oxides (NO_x) to nitrogen and oxygen. However, as lead is able to "poison" or deactivate the catalyst, the more stringent exhaust emission standards introduced in 1986 necessitated the use of unleaded petrol. Sulphur also adversely affects catalyst performance and durability, and regulation of the sulphur content of petrol has led to lower emissions of sulphur dioxide.

Increasingly sophisticated emission control technologies have been employed progressively to meet emission standards, commencing with tighter control of air/fuel mixtures and exhaust gas recirculation on the mid-1970s. Current vehicle models are equipped with computer-operated engine management systems, oxygen sensors and three-way catalytic converters, enabling catalysts to operate at optimal conversion efficiency during different modes of engine operation.

Vehicle emissions are being further reduced by increasing catalyst durability, improving the control of evaporative emissions, and using computerised diagnostic systems that identify malfunctioning emission controls. General improvements in vehicle technology and fuel efficiency are also resulting in overall emission reductions.

Evaporative emissions have been controlled primarily through design features in the fuel system. Reducing the volatility of petrol (especially in summer) has also enabled reductions in evaporative emissions.

2.3.3 Factors Affecting Vehicle Emissions

The principal factors affecting vehicle emissions that will be considered in this manual are:

- the vehicle type;
- the type and composition of the fuel used by a vehicle;
- the age of a vehicle; and
- the types of roads on which a vehicle travels.

The emission control technologies employed by an in-service vehicle, the condition of its emission control equipment, and its state of maintenance and repair, have significant impacts on emissions. These factors are reflected in the emissions estimation techniques by considering the age of particular types of vehicles. In particular, the original emission quality and subsequent emission deterioration with time may be simulated by the use of deterioration factors based on the average distance travelled by vehicles of different ages. These deterioration factors have been developed from Australian test data, but only for petrol-fuelled passenger vehicles.

Emissions also vary significantly with vehicle and engine operation, which in turn are strongly related to road types (selected on the basis of traffic flow conditions), and hence vehicle speeds and driving patterns. These factors are addressed in this manual by considering a variety of road types in the EETs.

Reid Vapour Pressure (RVP), temperature and number of trips per day have important effects on evaporative emissions. Typical average figures for these factors will be used in the EETs.

Other factors affecting motor vehicle emissions, including road conditions and grade, weather conditions, the proportions of hot and cold starts, and the use of air conditioners, are not considered in this manual, as the activity data to model the effects of these factors on emissions are not yet widely available.

3.0 Emissions Estimation Techniques

3.1 Activity Data Required

The following activity data and related information are required for estimating annual emissions from motor vehicles in an airshed:

- traffic count data or spatially distributed vehicle kilometres travelled (VKT) data by road type in an airshed;
- relative VKT by vehicle type on each road type in the airshed;
- VKT in a jurisdiction by vehicle/fuel type and year of manufacture;
- the number of vehicles in a jurisdiction by vehicle/fuel type and year of manufacture;
- the average fuel consumption rate of each vehicle/fuel type;
- the sulphur and lead contents of fuels and RVP of petrol used in an airshed; and
- the average temperature and average daily maximum and minimum temperatures (preferably for each month, otherwise for a year) in the airshed.

Traffic count data or spatial VKT data by road type are usually available from traffic authorities in a jurisdiction. Relative VKT by vehicle type and road type may be available from traffic authorities. Otherwise, the default values in Table 5 can be used. Data for a jurisdiction on VKT, vehicle numbers and fuel consumption for various vehicle/fuel type combinations can be purchased from the Australian Bureau of Statistics (ABS) or some private transport consultancies. Since the data on VKT and vehicle numbers are only used in the EET in a relative way (i.e. as ratios or proportions), they do not need to be converted to airshed data.

The sulphur and lead contents of fuels and RVP data are usually available from oil companies or the Australian Institute of Petroleum (AIP). Temperature data are available directly from the Bureau of Meteorology (BOM) or from its web site (http://www.bom.gov.au/climate/).

The road types considered in this manual are:

- *Arterial*: Major roads with moderate average speed (30 km hr^{-1}) and moderate congestion levels (typically 20% idle time);
- *Freeway*: Major roads with high average speeds (in excess of 40 km hr^{-1}) and low congestion levels (less than 5% idle time); and
- *Residential*: Secondary roads with moderate average speed and negligible levels of congestion.

Other road types such as commercial arterial and commercial highway are used in some jurisdictions. The emission factors for these road types may be approximated by those for the arterial and freeway types respectively, and will not be developed separately in the manual.

The congested road type is also not directly considered in this manual. For the NPI there is no requirement to temporally distribute emissions (e.g. to estimate the diurnal variation of emissions associated with different levels of congestion on a typical day). The consideration of congested road type is only important when emissions in heavily trafficked situations (such as central business districts during peak hours) need to be modelled. Since the NPI is concerned with annual emissions, the average (moderate) congestion level used for arterial roads is sufficient for estimation purposes. The impacts of congestion on emissions from passenger cars are effectively considered by developing emission factors for the above three road types. For other vehicle types the impacts of congestion on the overall inventory are less significant because of their relatively smaller VKT.

The vehicle types and fuel types that are considered in this manual are:

- petrol, diesel and LPG-fuelled passenger vehicles;
- petrol, diesel and LPG-fuelled light commercial vehicles;
- petrol, diesel and LPG-fuelled heavy duty vehicles; and
- petrol-fuelled motorcycles.

Leaded and unleaded petrol are distinguished in the EET only in relation to data on fuel consumption and the lead and sulphur contents of petrol. These factors affect emissions of lead and SO_2.

ABS does not supply data for LPG-fuelled vehicles separately, but groups them as LPG/LNG/dual fuel. In this manual, emission factors for LPG will be applied to all vehicles using this group of fuels.

3.2 Approaches Employed

Emissions from motor vehicles are estimated by multiplying VKT figures by emission factors (expressed in grams per kilometre - the mass of a pollutant or NPI substance which is emitted per kilometre travelled by a vehicle). The emission factors vary for different road types, vehicle/fuel type combinations, vehicle ages, and emission processes (i.e. exhaust, evaporative, tyre and brake wear). Hence, when estimating emissions, emission factors need to be weighted according to the structure and composition of the vehicle fleet.

Equation 1 shows how motor vehicle emissions are estimated for a grid cell from data on spatial VKT by road type and fleet composition, and the relevant emission factors.

The derivation of gridded VKT and relative VKT according to vehicle, fuel and road types is described in Section 4. The means of deriving emission factors for CO, NO_x, VOCs, PM_{10}, SO_2 and lead are described in Sections 5 to 8.

Emission factors for some organic compounds which are NPI substances may be derived by multiplying the emission factor for total VOCs by the speciated weight fractions for those species. Similarly, emission factors for metals (and their compounds) which are NPI substances may be derived by speciating the PM_{10} emission factor (see Equation 2). The relevant speciation factors for VOCs and PM_{10} are presented in Sections 9 and 10.

The emission factors so derived can then be used with Equation 1 to estimate the annual emissions in a grid cell of a VOC or particulate species.

Table 4 summarises the methods presented in this manual for deriving emission factors for motor vehicles, which are described in details in Sections 5 to 10.

Equation 1: Estimating emissions from motor vehicles

$$E_c = 365 * 0.001 * \sum_r \left\{ v_{r,c} * \sum_m \sum_f \sum_p \left(x_{r,m,f} * e_{r,m,f,p} \right) \right\}$$

where

E_c = Annual emissions from motor vehicles in grid cell c, kg yr^{-1}

$v_{r,c}$ = Average daily VKT for road type r in grid cell c, km day^{-1}

$x_{r,m,f}$ = Relative VKT of vehicle type m and fuel type f on road type r

$e_{r,m,f,p}$ = Emission factor for vehicle type m, fuel type f and emission process type p (exhaust, evaporative, or tyre and brake wear) on road type r, g km^{-1}

365 = Conversion factor from day to year

0.001 = Conversion factor from grams to kilograms

Equation 2: Deriving the emission factor for an individual VOC or particulate species which is an NPI substance

The emission factor may be derived by multiplying the total VOCs or particulate (PM_{10}) emission factor by the speciated weight fraction for that species

$$e_{m,f,p,s} = e_{m,f,p} * w_{f,p,s}$$

where

$e_{m,f,p,s}$ = Emission factor for species s for vehicle type m, fuel type f and emission process p, g km^{-1}

$e_{m,f,p}$ = Emission factor for total VOCs or PM_{10} for vehicle type m, fuel type f and process p, g km^{-1}

$w_{f,p,s}$ = Weight fraction of species s for fuel type f and emission process p

Other methods may be used for estimating emissions from motor vehicles. These include the power-based model (Williams *et al* 1994), on-road measurements (EPAV 1999), trip-based emission estimates (USEPA 1995a), estimates based on operating hours (USEPA 1995a), fuel-based methods

(Singer and Harley 1996), speed and acceleration models (Joumard *et al* 1995) and traffic flow models (Matzoros and van Vliet 1992). At this point in time, the activity data required to implement these methods and models are generally not available for an airshed or jurisdiction, and some of these models are more suited to localised areas rather than large regions where substantial amounts of data are required to support the models. These models are therefore not considered further in this manual.

Table 4: Methods for Deriving Vehicle Emission Factors

Substance	Vehicle Type	Fuel	Method
CO, NO_x and VOCs	Passenger car	Petrol	Exhaust: based on vehicle test data in Australia Evaporative: MOBILE5a [a]
		Diesel	MOBILE5a
		LPG	Estimated from emission ratios of LPG and petrol-fuelled vehicles
	Light commercial	Petrol	MOBILE5a
		Diesel	MOBILE5a
		LPG	Estimated from emission ratios of LPG and petrol-fuelled vehicles
	Heavy duty	Petrol	MOBILE5a
		Diesel	MOBILE5a
		LPG	Estimated from emission ratios of LPG and petrol-fuelled vehicles
	Motorcycles	Petrol	MOBILE5a
PM_{10}	Petrol-fuelled vehicles		PART5 [b]
	Diesel-fuelled vehicles		PART5
	LPG-fuelled vehicles		Estimated from emission ratios of LPG and diesel-fuelled vehicles
	Brake and tyre wear		PART5
SO_2	All vehicle and fuel types		Based on sulphur content of fuels and fuel consumption
Lead	Petrol-fuelled vehicles		Based on lead content of petrol and fuel consumption
	Diesel-fuelled vehicles		Speciation of PM_{10} from diesel-fuelled vehicles
	LPG-fuelled vehicles		Speciation of PM_{10} from LPG-fuelled vehicles
Individual organic compounds	All vehicle and fuel types		Speciation of total VOCs
Metals and compounds	All vehicle and fuel types		Speciation of PM_{10}

[a] USEPA (1995c).
[b] USEPA (1995b).

4.0 Derivation of VKT Data

4.1 Gridded VKT

Traffic authorities can usually provide spatial VKT data for different road types in major cities in either Geographical Information System (GIS) or gridded format. VKT data provided in GIS format can be converted to gridded VKT if a GIS is available for a jurisdiction.

If only traffic count data are available, the method illustrated in Equation 3 may be used to estimate VKT from traffic counts. Traffic counts may not cover every part of a road network and assumptions are often necessary to estimate traffic numbers in those parts of the network which are not covered. Where traffic count data are not available (usually for residential roads), Equation 4 can be used to estimate VKT from these road types in a cell.

Equation 3: Deriving gridded VKT data from traffic counts

To use this method, the grid for the airshed should overlay the road network, and the length of each road segment in each cell should be measured. The VKT for each segment can then be estimated by multiplying the length of the segment by the traffic count figure. The total VKT for a grid cell can then be derived by summing the estimated VKT for all road segments in the cell.

$$v_{r,c} = \sum_{i} t_{r,c,i} * L_{r,c,i}$$

where

$v_{r,c}$ = Average daily VKT for road type r in grid cell c, km day^{-1}
$t_{r,c,i}$ = Average daily traffic count for road link i of road type r in grid cell c, day^{-1}
$L_{r,c,i}$ = Length of road link i of road type r in grid cell c, km

Equation 4: Deriving gridded VKT data for residential roads from population data

$$v_{r=residential,c} = 2.41 * p_c$$

where

$v_{r=residential,c}$ = Average daily VKT for residential roads in grid cell c, km day^{-1}
2.41 = Average daily VKT per capita, km day^{-1}
p_c = Population in grid cell c

The value of the average daily VKT per capita is based on that of Dandenong in Victoria and Newcastle in NSW (EPAV 1996b). Gridded population data can be developed from data obtainable from the ABS (refer to other Aggregated Emissions manuals, such as the manual for Architectural Surface Coatings, for details of this technique).

If no spatial VKT data or traffic count data are available, VKT can be allocated according to population using Equation 5. Total VKT data are usually provided by ABS for a full year, and must be converted to daily averages.

Equation 5: Deriving gridded VKT data from population data

$$v_c = \frac{V}{P} * p_c$$

where

v_c = Average daily VKT in grid cell c, km day^{-1}
V = Total daily VKT in a jurisdiction, km day^{-1}
P = Total population in the jurisdiction
p_c = Population in grid cell c

It should be noted that there is no way to distinguish between road types if gridded VKT is derived in this manner, and it is recommended that emission factors for arterial roads should be used for emissions estimation.

4.2 Relative VKT by Vehicle, Fuel and Road Types

If relative VKT by road type and vehicle type is not available from traffic authorities, the default values in Table 5 can be used.

Table 5: Relative VKT by Vehicle Type on Different Road Types ($x_{r,m}$) [a]

Vehicle Type	Arterial or Freeway	Commercial Arterial or Commercial Highway	Residential
Passenger	0.806	0.752	0.8975
Light commercial	0.131	0.142	0.0655
Heavy duty	0.052	0.095	0.026
Motorcycle	0.011	0.011	0.011
Total	1.000	1.000	1.000

[a] Source: EPAV (1991).

The relative VKT by vehicle, fuel and road type may be derived from Equation 6. The relative VKT by *vehicle/fuel type* for each road type may be derived by applying ABS data on total VKT in the airshed by vehicle/fuel type to the figures for relative VKT by vehicle type. That is, the fractions of VKT on a road type by a particular *vehicle type* (e.g. passenger vehicles) may be further distributed to each *vehicle/fuel type combination* (e.g. petrol, diesel and LPG-fuelled passenger vehicles) by applying ABS estimates of the proportions of VKT in the jurisdiction by each of these vehicle/fuel types.

Equation 6: Deriving relative VKT by vehicle, fuel and road types

$$x_{r,m,f} = \frac{\sum_{y} v_{m,f,y}}{\sum_{f}\sum_{y} v_{m,f,y}} * x_{r,m}$$

where

$x_{r,m,f}$ = Relative VKT of vehicle type m and fuel type f on road type r

$v_{m,f,y}$ = Total VKT of vehicle type m, fuel type f and year of manufacture y on road type r, km

$x_{r,m}$ = Relative VKT of vehicle type m on road type r (Table 5)

4.3 VKT According to Vehicle Age

In estimating emission factors for CO, NO_x and VOCs for petrol-fuelled passenger vehicles, it is necessary to find the average cumulative VKT (i.e. the total distance accumulated over the vehicle's life) and relative VKT by vehicles (i.e. fraction of the total VKT by this vehicle type) in *different age groups* in this vehicle category (see Section 5.1.1).

The ABS supplies data on total VKT and vehicle numbers by year of manufacture for petrol-fuelled passenger vehicles, which is easily converted to data by age for a particular reporting year (see Table 6). The average VKT for vehicles of each age is obtained by dividing the total VKT by the number of vehicles of that age. The average cumulative VKT is the cumulative sum of the average VKT over the various vehicle ages (see Table 6). Of course, using the data in Table 6 to calculate cumulative VKT data over the life of a vehicle assumes that these data are time-invariant (i.e. equally applicable in different calendar years).

Equation 7 illustrates how average cumulative VKT of each age group is derived from average cumulative VKT of each age, and Equation 8 shows how relative VKT is derived from total VKT for different age groups.

Table 6: National VKT and Vehicle Numbers by Age for Petrol-Fuelled Passenger Vehicles [a]

Age [b] **(years)** **y**	**Total VKT (10^6 km)** v_y	**Number of Vehicles** n_y	**Average VKT (10^3 km/vehicle)** v_y/n_y	**Average Cummulative VKT (10^3 km)** c_y
>21 [c]	7969	831651	9.58	314
20	1906	91681	20.8	304
19	2278	212097	10.7	284
18	3740	228244	16.4	273
17	2385	229308	10.4	256
16	2994	265442	11.3	246
15	4140	286005	14.5	235
14	5041	427470	11.8	220
13	4398	382752	11.5	209
12	5025	344784	14.6	197
11	4963	454877	10.9	182
10	4481	381959	11.7	172
9	7373	436359	16.9	160
8	3596	310855	11.6	143
7	3298	261841	12.6	131
6	9158	526180	17.4	119
5	5348	347544	15.4	101
4	6014	392544	15.3	86.0
3	7949	433147	18.4	70.7
2	8855	474459	18.7	52.3
1	11319	503006	22.5	33.7
0 [d]	1605	143964	11.1	11.1
Total	114370	8014157	-	-

[a] Source: ABS (1996).
[b] Data are supplied by year of manufacture but expressed in terms of age.
[c] ABS does not break down data for vehicles older than 21 years. It is assumed that vehicles in this age group are 21 to 30 year old and that total VKT and vehicle numbers are the same for all vehicle ages in this range.
[d] Data include statistics up to the end of September but are scaled up to a full year.

Equation 7: Deriving average cumulative VKT by age group

$$c_{y1-y2} = \frac{\sum_{y=y1}^{y2} n_y * c_y}{\sum_{y=y1}^{y2} n_y}$$

where

$c_{y1\text{-}y2}$ = Average cumulative VKT for age group y1-y2, km
n_y = Number of vehicles of age y
c_y = Average cumulative VKT for vehicles of age y, km

Equation 8: Deriving relative VKT by age group

$$x_{y1-y2} = \frac{\sum_{y=y1}^{y2} v_y}{\sum_{y} v_y}$$

where

$x_{y1\text{-}y2}$ = Relative VKT for age group y1-y2
v_y = Total VKT for vehicles of age y, km yr^{-1}

Table 7: National Fleet Average Cumulative VKT and Relative VKT by Vehicle Age for Petrol-Fuelled Passenger Vehicles

Age Group y1-y2	Age (years) [a]	Average Cumulative VKT (10^3 km) $c_{y1\text{-}y2}$	Relative VKT $x_{y1\text{-}y2}$
Pre-1976	Over 24	314	0.0418
1976-1985	15 to 24	271	0.180
1986-1996	4 to 14	157	0.513
Post-1996	0 to 3	46.5	0.265
Total	-	-	1.00

[a] The age presented in the table is with respect to a reporting year of 2000.

It should be noted that the figures in Table 7 are national averages derived for the year 2000. The relative VKT of post-1996 vehicles will obviously increase over the years, while that of the older age groups of vehicles will decline.

5.0 Emission Factors for CO, NO_x and VOCs

5.1 Exhaust Emission Factors

5.1.1 Petrol-Fuelled Passenger Vehicles

Emissions of CO, NO_x and VOCs depend on vehicle age, as older vehicles have been designed to meet less stringent standards when new, and all vehicles, regardless of their initial design or emissions performance, tend to emit more pollutants as they age. Increased emissions occur because of "wear and tear" and failure of vehicle components, lower levels of vehicle maintenance, and the reduced efficiency of emission controls (e.g. the conversion efficiency of catalysts deteriorates with distance).

Equation 9 shows how exhaust emission factors are calculated from deterioration rates and average cumulative VKT. This equation assumes that there is no further deterioration after 150 000 km of travel. The basis of this assumption is the notion that the positive impacts of engine replacement after this distance will offset any further deterioration.

Table 8 shows the values of deterioration rates and zero-kilometre emissions to be used in these calculations.

The method for estimation of emission factors averaged over the various age groups is shown in Equation 10.

Table 11 shows the emission factors for petrol-fuelled passenger vehicles which have been derived from these equations, using the VKT data from Table 7.

Equation 9: Estimating exhaust emission factors for CO, NO_x and VOCs for different age groups of petrol-fuelled passenger vehicles

$$e_{r,p,y1-y2} = e^{o}_{r,p,y1-y2} + d_{p,y1-y2} * 150 \qquad c_{y1-y2} > 150\ 000\ \text{km}$$

$$e_{r,p,y1-y2} = e^{o}_{r,p,y1-y2} + d_{p,y1-y2} * c_{y1-y2} \qquad c_{y1-y2} \leq 150\ 000\ \text{km}$$

where

$e_{r,p,y1-y2}$ = Emission factor for road type r, pollutant p and age group y1-y2 after applying deterioration rate, g km^{-1}
$e^{\circ}_{r,p,y1-y2}$ = Zero-kilometre emission for road type r, pollutant p and age group y1-y2, g km^{-1} (see Table 8)
$d_{p,y1-y2}$ = Deterioration rate (per VKT) for pollutant p and age group y1-y2, g km^{-1} $[10^3 km]^{-1}$ (see Table 8)
c_{y1-y2} = Average cumulative VKT for age group y1-y2, 10^3 km (see Equation 7)

Table 8: Deterioration Rates and Zero-Kilometre Emissions for Petrol-Fuelled Passenger Vehicles

Age Group y1-y2	Deterioration Rate[a] ($g\ km^{-1}[10^3\ km]^{-1}$) $d_{p,y1-y2}$	Zero-Kilometre Emission [a] ($g\ km^{-1}$) $e°_{r,p,y1-y2}$		
		Arterial	**Freeway**	**Residential**
CO				
Pre-1976	0.133	16.4	10.9	23.7
1976-1985	0.127	10.4	6.92	15.0
1986-1996	0.131	1.41	2.05	4.66
Post-1996	0.131 [b]	0.319 [c]	0.463 [c]	1.05 [c]
NO_x				
Pre-1976	-0.00366	2.13	3.71	2.72
1976-1985	0.00694	1.10	1.91	1.40
1986-1996	0.00921	0.515	0.820	0.707
Post-1996	0.00921 [b]	0.168 [c]	0.268 [c]	0.231 [c]
VOCs				
Pre-1976	0.0106	1.64	1.37	2.09
1976-1985	0.00740	1.10	0.918	1.40
1986-1996	0.00738	0.115	0.155	0.312
Post-1996	0.00738	0.0322	0.0435	0.0873

[a] Derived from vehicle test data from EPANSW and EPA of Victoria (EPAV 1996b) unless otherwise specified. Deterioration rate is per VKT.
[b] Assumed to be the same as the 1986 -1996 deterioration rate.
[c] No test data available. Estimated from the ratio of emission standards (see Table 2) and 1986 -1996 zero-kilometre emissions.

Equation 10: Estimating exhaust emission factors for CO, NO_x and VOCs for petrol-fuelled passenger vehicles averaged over all age groups

$$e_{r,p} = \sum_{y1-y2} e_{r,p,y1-y2} * x_{y1-y2}$$

where

$e_{r,p}$ = Fleet average emission factor for road type r and pollutant p for vehicle fleet, $g\ km^{-1}$

$e_{r,p,y1-y2}$ = Emission factor for road type r, pollutant p and age group y1-y2 after correcting for deterioration, $g\ km^{-1}$

x_{y1-y2} = Relative VKT for age group y1-y2 (see Equation 8 and Table 7)

5.1.2 Other Petrol-Fuelled and Diesel-Fuelled Vehicles

Very limited Australian test data (Williams *et al* 1989a, 1989b; Watson *et al* 1987) are available for other petrol and diesel-fuelled vehicles. It is recommended that MOBILE5a be used to estimate emissions for these vehicles. MOBILE5a is a software package developed by USEPA to calculate exhaust and evaporative emission factors for the US passenger and commercial vehicle fleet. The software is available on the USEPA web site (http://www.epa.gov/orcdizux/m5.htm). A new version, MOBILE6 (USEPA 1998b), is under development and may provide an improved estimation tool when it is released.

The following data are required as inputs to MOBILE5a:

- relative vehicle miles travelled (VMT) in an airshed by vehicle/fuel type;
- VMT in the airshed by vehicle/fuel type and age;
- number of vehicles in the airshed by vehicle/fuel type and age;
- RVP, average temperature and average daily maximum and minimum temperatures in the reporting year in the airshed.

Obviously, the VMT data need to be calculated from equivalent VKT data by converting from kilometres to miles). The other data are complementary to those data for petrol-fuelled passenger vehicles, and should be accessed and processed similarly.

It should be noted that emission standards in Australia lag behind those in the USA, and a time lag of about 3 years should therefore be used as the calendar year when running the program. This time lag is smaller than Section 2.3.1 would suggest, as most commercial vehicles in Australia are imported and many would have in-built emission controls that are required for markets with more stringent requirements than Australia.

The relationships between vehicle types and MOBILE5a classifications (Table 9) should be used in preparing the MOBILE5a input file. A sample of an input file is shown in Appendix A, based on national VKT and registration data.

Table 9: Relationships between Vehicle Types Used in the Manual and MOBILE5a Classifications

Vehicle Type	Fuel	MOBILE5 Classification	Abbreviation
Passenger	Petrol	Light Duty Gasoline-powered Vehicle	LDGV
	Diesel	Light Duty Diesel-powered Vehicle	LDDV
Light commercial	Petrol	Light Duty Gasoline-powered Truck (Type 1)	LDGT1
	Diesel	Light Duty Diesel-powered Truck	LDDT
Heavy Duty [a]	Petrol	Heavy Duty Gasoline-powered Vehicle	HDGV
	Diesel	Heavy Duty Diesel-powered Vehicle	HDDV
Motorcycle	Petrol	Motorcycle	MC

[a] Includes articulated trucks, non-freight carrying trucks, rigid trucks and buses.

Emission factors from MOBILE5a are based on vehicle test results in the US at an average speed of 19.6 miles per hour. If this speed is used in running MOBILE5a, Equation 11 and Table 10 can be used to derive emission factors for different road types. Table 11 shows the results for petrol and diesel-fuelled vehicles, based on national VKT and registration data for the reporting year 2000.

Equation 11: Correcting exhaust emission factors for CO, NO_x and VOCs obtained from MOBILE5a for different road types

$$e_{r,p} = e_p * j_{r,p}$$

where

$e_{r,p}$ = Emission factor for road type r and pollutant p, g km^{-1}
e_p = MOBILE5a emission factor for pollutant p, g km^{-1}
$j_{r,p}$ = Correction factor for road type r and pollutant p (Table 10)

Table 10: Correction Factors for MOBILE5a Exhaust Emission Factors for Different Road Types [a]

Substance	Arterial	Freeway	Residential
CO	0.562	0.454	1
NO_x	0.766	1.30	1
VOCs	0.650	0.604	1

[a] Derived from EPAV (1996b).

5.1.3 LPG-Fuelled Vehicles

Exhaust emission factors for LPG-fuelled vehicles are estimated from emission ratios for vehicles fuelled by LPG and petrol respectively (see Equation 12). Table 11 shows the factors obtained from using this equation.

The emission ratios are based on the most recent Australian study by the Australian Liquefied Petroleum Gas Association (ALPGA 1993), the findings of which differ from those obtained by Pengilley (1989) and Ken-Allan (1991).

Equation 12: Estimating exhaust emission factors for CO, NO_x and VOCs for LPG-fuelled vehicles

$$e_{m,f=LPG,r,p} = e_{m,f=petrol,r,p} * j_p$$

where

$e_{m,f=LPG,r,p}$= Emission factor for vehicle type m, LPG fuel, road type r and pollutant p, g km^{-1}
$e_{m,f=petrol,r,p}$= Emission factor for vehicle type m, petrol fuel, road type r and pollutant p, g km^{-1}
j_p = Emission ratio for LPG and petrol-fuelled vehicles

and

j_{CO} = 0.16/0.15
j_{NOx} = 0.69/1.04
j_{VOCs} = 3.58/3.22

5.2 Evaporative Emission Factors

Evaporative emission factors from petrol-fuelled vehicles are estimated from MOBILE5a (see Section 5.1.2). MOBILE5a also estimates refuelling losses. However, these emissions are already covered by the manual for Aggregated Emissions from Service Stations and should not be included in the evaporative emissions.

Evaporative emission factors are the same for different road types, except that running losses on freeway are 10% of those on arterial roads (EPAV 1996a). Evaporative emission factors for petrol-fuelled vehicles, assuming an average daily temperature of 15°C, a minimum of 10°C, a maximum of 20°C and a RVP of 10 psi in MOBILE5a, are shown in Table 11.

Evaporative emissions from diesel vehicles are comparatively very low because diesel is not very volatile. These emissions need not be estimated.

A study by EPANSW (1997) shows that evaporative emissions from LPG-fuelled vehicles are about twice of those from petrol-fuelled vehicles. This assumption is used in deriving evaporative the emission factors for LPG-fuelled vehicles in Table 11.

5.3 Summary of Emission Factors for CO, NO_x and VOCs

Table 11 shows emission factors that are derived from national VKT and registration data, for the reporting year 2000. If a jurisdiction lacks the expertise or resources to develop the necessary emission factors, the values of the factors in Table 11 may be used as default values in applying Equation 1.

Table 11: Emission Factors for CO, NO_x and VOCs by Vehicle, Fuel and Road Types

Vehicle Type	Fuel	Emission Factor (g km^{-1})		
		Arterial	Freeway	Residential
CO				
Passenger	Petrol	19.3	18.8	22.3
	Diesel	0.637	0.516	1.13
	LPG	24.5	24.0	27.9
Light commercial	Petrol	17.2	13.9	30.6
	Diesel	0.810	0.656	1.44
	LPG	19.1	15.4	34.0
Heavy duty	Petrol	53.7	43.4	95.6
	Diesel	4.42	3.58	7.87
	LPG	59.7	48.3	106
Motorcycle	Petrol	9.04	7.32	16.1
NO_x				
Passenger	Petrol	1.58	1.98	1.78
	Diesel	0.785	1.33	1.02
	LPG	1.10	1.37	1.23
Light commercial	Petrol	1.32	2.24	1.73
	Diesel	1.03	1.75	1.35
	LPG	0.878	1.49	1.15
Heavy duty	Petrol	3.08	5.21	4.02
	Diesel	6.69	11.3	8.73
	LPG	2.04	3.46	2.66
Motorcycle	Petrol	0.428	0.724	0.558
VOCs (exhaust)				
Passenger	Petrol	1.26	1.24	1.45
	Diesel	0.331	0.310	0.513
	LPG	1.53	1.51	1.73
Light commercial	Petrol	1.64	1.53	2.53
	Diesel	0.554	0.517	0.857
	LPG	1.75	1.63	2.70
Heavy duty	Petrol	3.08	2.88	4.77
	Diesel	1.01	0.941	1.56
	LPG	3.29	3.07	5.09
Motorcycle	Petrol	1.23	1.15	1.90
VOCs (evaporative)				
Passenger	Petrol	0.535	0.241	0.535
	LPG	1.07	0.483	1.07
Light commercial	Petrol	0.586	0.275	0.586
	LPG	1.17	0.550	1.17
Heavy duty	Petrol	2.91	2.15	2.91
	LPG	5.81	4.29	5.81
Motorcycle	Petrol	0.803 [a]	0.803	0.803

[a] Running losses are not estimated by MOBILE5a for motorcycles, and hence these emissions are assumed to be the same for all road types.

However, it is recommended that the emission factors for petrol-fuelled passenger vehicles (at least) are developed for a jurisdiction since they usually constitute most of the emissions.

6.0 Emission Factors for PM_{10}

There have been very few studies of particulate emissions from motor vehicles in Australia. Williams *et al* (1989a, 1989b) have reported particulate emissions from petrol and diesel-fuelled vehicles. However, these studies used relatively small samples of pre-1987 vehicles, so the results may not be applicable to the current vehicle "fleet". It is therefore recommended that PART5 is used to estimate these emissions. The PART5 software has been developed by the USEPA to calculate emission factors of particulate matter for the US passenger and commercial vehicle fleet. This software is available on the USEPA web site at http://www.epa.gov/oms/part5.htm).

The following data are required as inputs to PART5:

- relative vehicle miles travelled (VMT) by vehicle/fuel types;
- total VMT by vehicle type and age; and
- number of vehicles by vehicle type and age.

Emission standards in Australia lag behind those in the USA, and a time lag of about 3 years should be used as the calendar year when running the program. This time lag is smaller than Section 2.3.1 would suggest, for the same reasons discussed in Section 5.1.2 in relation to MOBILE5a.

The relationships in Table 12 between vehicle types and the PART5 classifications should be used in preparing the PART5 input file. A sample input file is shown in Appendix B, based on national data.

Table 12: Relationships between Vehicle Types Used in the Manual and PART5 Classifications

Vehicle Type	Fuel	PART5 Classification	Abbreviation
Passenger	Petrol	Light Duty Gasoline-powered Vehicle	LDGV
	Diesel	Light Duty Diesel-powered Vehicle	LDDV
Light Commercial	Petrol	Light Duty Gasoline-powered Truck (Type 1)	LDGT1
	Diesel	Light Duty Diesel-powered Truck	LDDT
Heavy Duty [a]	Petrol	Heavy Duty Gasoline-powered Vehicle	HDGV
	Diesel	Medium Heavy Duty Diesel-powered Vehicle	MHDDV
Bus	Petrol	Bus [b]	BUSES
	Diesel	Bus [b]	BUSES
Motorcycle	Petrol	Motorcycle	MC

[a] Includes articulated truck, non-freight carrying truck and rigid truck.
[b] PART5 does not distinguish between petrol and diesel. Most Australian buses are diesel-engined, and it is likely that PART5 emission factor is also based on diesel use.

PART5 also estimates dust emissions from paved and unpaved roads. However, these emissions are already covered by the Aggregated Emissions manual for Paved and Unpaved Roads and should not be included in the vehicle emissions.

Exhaust emission factors for LPG-fuelled vehicles are estimated from the emission ratios of LPG and diesel-fuelled vehicles (see Equation 13). Exhaust emission factors on freeways are assumed to be 55% of those on arterial roads (Gabele *et al* 1986).

Equation 13: Estimating exhaust emission factors for PM_{10} for LPG-fuelled vehicles

$$e_{m,f=LPG,r} = e_{m,f=diesel,r} * j_m$$

where

$e_{m,f=LPG,r}$ = Emission factor for vehicle type m, LPG fuel and road type r, g km^{-1}

$e_{m,f=diesel,r}$ = Emission factor for vehicle type m, diesel fuel and road type r, g km^{-1}

j_m = Emission ratio of LPG and diesel-fuelled vehicles

and

j_m = 0.002/0.090 for passenger, light commercial and motorcycle vehicle types

= 0.010/0.021 for heavy duty (and bus) vehicle types (Parsons 1998)

Table 13 shows emission factors that have been derived from national VKT and registration data for the year 2000. If a jurisdiction lacks expertise or resources to develop the necessary emission factors, the values in Table 13 may be used as default values in applying Equation 1.

Table 13: Emission Factors for PM_{10} by Vehicle, Fuel and Road Types

Vehicle Type	Fuel	Emission Factor (g km^{-1})		
		Arterial	**Freeway**	**Residential**
Exhaust				
Passenger	Petrol	0.00932	0.00513	0.00932
	Diesel	0.148	0.0813	0.148
	LPG	0.00329	0.00181	0.00329
Light commercial	Petrol	0.0118	0.00649	0.0118
	Diesel	0.222	0.122	0.222
	LPG	0.00493	0.00271	0.00493
Heavy duty [a]	Petrol	0.120	0.0660	0.120
	Diesel	0.584	0.321	0.584
	LPG	0.0278	0.0153	0.0278
Bus	Petrol [b]	0.666	0.366	0.666
	Diesel [b]	0.666	0.366	0.666
	LPG	0.0317	0.0174	0.0317
Motorcycle	Petrol	0.0124	0.00684	0.0124
Tyre Wear				
Passenger		0.00497	0.00497	0.00497
Light commercial		0.00497	0.00497	0.00497
Heavy duty		0.00746	0.00746	0.00746
Bus		0.00497	0.00497	0.00497
Motorcycle		0.00249	0.00249	0.00249
Brake Wear				
All vehicles		0.00808	0.00808	0.00808

[a] Includes articulated truck, non-freight carrying truck and rigid truck
[b] PART5 does not distinguish between petrol and diesel for the emission factor for buses.

Use of the above emission factors for deriving estimates of emissions from heavy duty vehicles (excluding buses) on the one hand and buses on the other, obviously requires separate estimates of relative VKT (by road type) for these two sub-categories of heavy duty vehicles. As ABS data on VKT by vehicle type is provided in a disaggregated form (i.e. by different categories of heavy duty vehicles), this requirement presents no problem.

7.0 Emission Factors for SO_2

Emission factors for SO_2 are estimated from the fuel sulphur contents and fuel consumption rates of the various vehicle types (see Equation 14).

If data on the local sulphur contents of fuels are not available, the values in Table 14, which are national averages, can be used as default values for an airshed.

Equation 14: Estimating emission factors for SO_2

$$e_{m,f,r} = u_{m,f} * w_f * j_r * 0.98 * 2$$

where

$e_{m,f,r}$ = Emission factor for vehicle type m, fuel type f and road type r, g km^{-1}
$u_{m,f}$ = Average fuel consumption for vehicle type m and fuel type f, L km^{-1}
w_f = Sulphur content of fuel f, g L^{-1}
j_r = Correction factor for road type r
0.98 = proportion of sulphur in fuel which is converted into SO_2 (USEPA 1995b)
2 = ratio of mass of SO_2 to mass of sulphur

and

j_r = 1 for arterial or residential roads
= 0.7 for freeways (EPAV 1996a)

Table 14: Sulphur Contents of Fuels

Fuel	Sulphur Content (g L^{-1})
Leaded petrol	0.155 [a]
Unleaded petrol	0.110 [a]
Diesel	1.27 [b]
LPG	0.00784 [c]

[a] National averages from AIP (1998).
[b] National average from AIP (1997).
[c] Average from EPAV (1996b).

Table shows emission factors derived from the national average fuel consumption and sulphur content.

Table 15: Average Fuel Consumption and Emission Factors for SO_2 by Vehicle, Fuel and Road Types

Vehicle Type	Fuel	Average Fuel Consumption (L km^{-1}) [a]	Emission Factor (g km^{-1})		
			Arterial	Freeway	Residential
Passenger vehicle	Leaded petrol	0.117	0.0362	0.0254	0.0362
	Unleaded petrol	0.109	0.0239	0.0168	0.0239
	Diesel	0.112	0.285	0.199	0.285
	LPG	0.174	0.00273	0.00191	0.00273
Light commercial vehicle	Leaded petrol	0.136	0.0421	0.0295	0.0421
	Unleaded petrol	0.124	0.0272	0.0191	0.0272
	Diesel	0.119	0.302	0.212	0.302
	LPG	0.167	0.00262	0.00183	0.00262
Rigid truck	Leaded petrol	0.231	0.0715	0.0501	0.0715
	Unleaded petrol	0.213	0.0468	0.0327	0.0468
	Diesel	0.272	0.691	0.484	0.691
	LPG	0.320	0.00502	0.00351	0.00502
Articulated truck	Leaded petrol	0.436	0.135	0.0945	0.135
	Unleaded petrol	0.00	0.00	0.00	0.00
	Diesel	0.506	1.29	0.900	1.29
	LPG	0.810	0.0127	0.00889	0.0127
Non-freight carrying truck	Leaded petrol	0.248	0.0768	0.0538	0.0768
	Unleaded petrol	0.233	0.0512	0.0358	0.0512
	Diesel	0.253	0.643	0.450	0.643
	LPG	0.310	0.00486	0.00340	0.00486
Bus	Leaded petrol	0.234	0.0725	0.0507	0.0725
	Unleaded petrol	0.134	0.0294	0.0206	0.0294
	Diesel	0.289	0.734	0.514	0.734
	LPG	0.337	0.00528	0.00370	0.00528
Motorcycle	Leaded petrol	0.0570	0.0176	0.0124	0.0176
	Unleaded petrol	0.0590	0.0130	0.00907	0.0130

[a] National averages from ABS (1996).

Use of the above emission factors for deriving estimates of emissions from (i) rigid trucks, (ii) articulated trucks, (iii) non-freight carrying trucks and (iv) buses on the other, obviously requires separate estimates of relative VKT (by road type) for these four sub-categories of heavy duty vehicles. As ABS data on VKT by vehicle type is provided in a disaggregated form (i.e. by different categories of heavy duty vehicles), this requirement presents no problem.

8.0 Emission Factors for Lead

Emission factors for lead for petrol-fuelled vehicles are estimated from the fuel lead contents and fuel consumption rates of the various vehicle types (see Equation 16).

If data on the local lead contents of fuels are not available, the values in Table 16, which are national averages, can be used as default values for an airshed.

Table 17 shows emission factors derived from national average fuel consumption figures (see Table 15) and lead contents.

Equation 15: Estimating emission factors for lead for petrol-fuelled vehicles

$$e_{m,f,r} = u_{m,f} * w_f * j_r * 0.77$$

where

$e_{m,f,r}$ = Emission factor for vehicle type m, fuel type f and road type r, g km^{-1}
$u_{m,f}$ = Average fuel consumption of vehicle type m and fuel type f, L km^{-1}
w_f = Lead content of fuel f, g L^{-1}
j_r = Correction factor for road type r
0.77 = proportion of lead in petrol that is emitted to air (Biggins and Harrison 1979)

and

j_r = 1 for arterial or residential roads
= 0.7 for freeways (EPAV 1996a)

Table 16: Lead Contents of Fuels

Fuel	Lead Content (g L^{-1}) [a]
Leaded petrol	0.13
Unleaded petrol	0.00140

[a] National averages from AIP (1998).

Table 17: Emission Factors for Lead by Vehicle and Road Types for Petrol-Fuelled Vehicles

Vehicle Type	Fuel	Emission Factor (g km^{-1})		
		Arterial	**Freeway**	**Residential**
Passenger	Leaded petrol	0.0117	0.00820	0.0117
	Unleaded petrol	0.000118	0.000082	0.000118
Light commercial	Leaded petrol	0.0136	0.0095	0.0136
	Unleaded petrol	0.000134	0.000094	0.000134
Rigid trucks	Leaded petrol	0.0231	0.0162	0.0231
	Unleaded petrol	0.000230	0.000161	0.000230
Articulated trucks	Leaded petrol	0.0436	0.0306	0.0436
	Unleaded petrol	0.00	0.00	0.00
Non-freight carrying trucks	Leaded petrol	0.0248	0.0174	0.0248
	Unleaded petrol	0.000251	0.000176	0.000251
Buses	Leaded petrol	0.0234	0.0164	0.0234
	Unleaded petrol	0.000144	0.000101	0.000144
Motorcycles	Leaded petrol	0.00571	0.00399	0.00571
	Unleaded petrol	0.0000636	0.0000445	0.0000636

Emission factors for diesel and LPG-fuelled vehicles are derived from speciation of PM_{10} emissions (see Section 10).

9.0 Speciation Factors for VOCs

Table 18 presents speciation factors that may be used to speciate VOC emissions from all types of vehicles.

Evaporative emissions from LPG-fuelled vehicles contain mainly propane and butane (the main constituents of LPG) and no NPI substance (Nelson and Duffy 1998).

Table 18: VOC Speciation of Emissions from Motor Vehicles

Substance	Weight Fraction			
	Petrol Exhaust [a]	**Petrol Evaporative** [a]	**Diesel Exhaust** [b]	**LPG Exhaust** [c]
Acetaldehyde	0.00437 [d]		0.155	0.000615
Acetone	0.00286 [d]		0.0815	
Benzene	0.0658	0.0170	0.0101	9.43×10^{-6}
1,3-Butadiene	0.00649	0.00180	0.00115	0.0000552
Cyclohexane	0.00111	0.000713	0.000778	
Ethylbenzene	0.0150	0.00190		
Formaldehyde	0.0156 [d]		0.0826	0.00178
n-Hexane	0.0155	0.0147		
PAHs	0.00217 [e]		0.00667	
Styrene	0.00213	0.000308		
Toluene	0.105	0.0224	0.0147	
Xylenes	0.0759	0.00992	0.0117	

[a] Derived from Duffy *et al* (in press), except where otherwise specified.
[b] Derived from Schauer *et al* (1999).
[c] Derived from Parsons (1998).
[d] Derived from Macauley (1990).
[e] Kahlili *et al* (1995).

10.0 Speciation Factors for PM_{10}

Table 19 presents speciation factors that may be used to speciate PM_{10} emissions from all types of vehicles.

Table 19: Particulate Speciation of Emissions from Motor Vehicles

Substance	Weight Fraction			
	Petrol Exhaust [a]	**Diesel Exhaust [b]**	**LPG Exhaust [c]**	**Tyre and Brake Wear [d]**
Cadmium and compounds		0.0006		
Chromium (III) compounds [e]	0.00007	0.00007	0.0055	
Chromium (VI) compounds [e]	0.00003	0.00003	0.0055	
Cobalt and compounds		0.0001	0.02	
Copper and compounds	0.0003	0.0001	0.0005	
Lead and compounds	[f]	0.0001	0.0005	
Manganese and compounds	0.0002	0.0001	0.0005	
Nickel and compounds	0.0001		0.0055	
Zinc and compounds	0.0051	0.0007	0.0055	0.01

[a] USEPA (1992).
[b] Schauer *et al* (1999).
[c] USEPA (1992), in which the speciation profile is based on a refinery process heater.
[d] USEPA (1992).
[e] Assuming the same fraction of chromium (VI) (29.3%) in PM_{10} emissions as that emitted from fuel oil combustion (USEPA 1998a).
[f] Covered in Section 8.

11.0 Sample Calculations

Example 1: Deriving relative VKT by vehicle and fuel types on arterial roads

Assuming a jurisdiction has the following VKT data for each vehicle and fuel type after summing over all years of manufacture

Vehicle Type	Fuel	Total VKT (10^3 km yr^{-1})
Passenger	petrol	113 835
	diesel	4 376
	LPG	5 480
Light commercial	petrol	17 498
	diesel	6 922
	LPG	3 330
Heavy duty	petrol	863
	diesel	12 646
	LPG	218
Motorcycle	petrol	1 526

The relative VKT of petrol-fuelled passenger vehicles on arterial roads is estimated from Equation 6 using the relative VKT by vehicle and road types data in Table 5 as

$$x_{r,m,f} = \frac{\sum_{y} v_{m,f,y}}{\sum_{f}\sum_{y} v_{m,f,y}} * x_{r,m}$$

= {113835 / (113835 + 4376 + 5480)} * 0.806
= 0.742

The following shows relative VKT figures calculated for all vehicle/fuel types

Vehicle Type m	Fuel f	By fuel	By vehicle $x_{r,m}$	By vehicle and fuel $x_{r,m,f}$
Passenger	petrol	0.920	0.806	0.742
	diesel	0.0354	0.806	0.0285
	LPG	0.0443	0.806	0.0357
Light commercial	petrol	0.631	0.131	0.0826
	diesel	0.249	0.131	0.0327
	LPG	0.120	0.131	0.0157
Heavy duty	petrol	0.0629	0.052	0.00327
	diesel	0.921	0.052	0.0479
	LPG	0.0159	0.052	0.000826
Motorcycle	petrol	1.00	0.011	0.011

Example 2: Estimating exhaust emission factors for VOCs for petrol-fuelled passenger vehicles on arterial roads in an age group

Assuming the average cumulative VKT data in Table 7, and using the vehicle test data in Table 8, the emission factor for pre-1976 vehicles petrol-fuelled passenger vehicles is estimated from Equation 9 as

$$e_{r,p,y1-y2} = e^{o}_{r,p,y1-y2} + d_{p,y1-y2} * 150 \qquad c_{y1\text{-}y2} > 150\ 000 \text{ km}$$

$$= 1.64 + 0.0106 * 150$$

$$= 3.23 \text{ g km}^{-1}$$

Emission factors for 1976-1986, 1987-1996 and post-1996 vehicles may be similarly estimated as 2.21, 1.22 and 0.375 g km^{-1} respectively.

Example 3: Estimating exhaust emission factors for VOCs for petrol-fuelled passenger vehicles on arterial roads over all age groups

Assuming the relative VKT by vehicle age data in Table 7, and using the results obtained in Example 2, the average emission factor over all age groups is estimated from Equation 10 as

$$e_{r,p} = \sum_{y1-y2} e_{r,p,y1-y2} * x_{y1-y2}$$

$$= 3.23 * 0.0418 + 2.21 * 0.180 + 1.22 * 0.513 + 0.375 * 0.265$$

$$= 1.26 \text{ g km}^{-1}$$

Example 4: Deriving emission factors for xylenes on arterial roads

Using the results derived in Example 3 and the relevant speciation factor in Table 18, the exhaust emission factor for xylenes from petrol-fuelled passenger vehicles is derived from Equation 2 as

$$e_{m,f,p,s} = e_{m,f,p} * w_{f,p,s}$$

$$= 1.26 * 0.0759$$

$$= 0.0956 \text{ g km}^{-1}$$

Using VOC emission factors from Table 11, xylene emission factors (g km^{-1}) for other vehicle/fuel types may be derived as follows

Vehicle Type m	Fuel f	VOCs $e_{m,f,p}$	Speciation $w_{f,p,s}$	Xylenes $e_{m,f,p,s}$
Exhaust				
Passenger	Petrol	1.26	0.0759	0.0956
	Diesel	0.331	0.0117	0.00387
Light commercial	Petrol	1.64	0.0759	0.124
	Diesel	0.554	0.0117	0.00648

Heavy duty	Petrol	3.08	0.0759	0.234
	Diesel	0.0117	1.01	0.0118
Motorcycle	Petrol	0.0759	1.23	0.0934
Evaporative				
Passenger	Petrol	0.00992	0.535	0.00531
Light commercial	Petrol	0.00992	0.586	0.00581
Heavy duty	Petrol	0.00992	2.91	0.0289
Motorcycle	Petrol	0.00992	0.803	0.00797

Example 5: Deriving VKT data from traffic counts for a grid cell

Assume a grid cell contains two arterial roads with the following data

Length (km)	Traffic Count (day^{-1})
2.4	4700
0.9	3100

VKT for arterial roads in the grid cell can be derived from Equation 3 as

$$v_{r,c} = \sum_i t_{r,c,i} * L_{r,c,i}$$

= 4700 * 2.4 + 3100 * 0.9

= 14 070 km day^{-1}

Example 6: Estimating emissions of xylenes in a grid cell from motor vehicles

Based on the VKT figure calculated for a grid cell in Example 5, the relative VKT data by vehicle/fuel types from Example 1, and the emission factors derived in Example 4, emissions of xylenes in the grid cell are estimated from Equation 1 as

$$E_c = 365 * 0.001 * \sum_r \left\{ v_{r,c} * \sum_m \sum_f \sum_p \left(x_{r,m,f} * e_{r,m,f,p} \right) \right\}$$

= 365 * 0.001 * {14070

* [0.742 * (0.0956 + 0.00531)	petrol passenger
+ 0.0285 * 0.00387	diesel passenger
+ 0.0826 * (0.124 + 0.00581)	petrol light commercial
+ 0.0327 * 0.00648	diesel light commercial
+ 0.00327 * (0.234 + 0.0289)	petrol heavy duty
+ 0.0479 * 0.0118	diesel heavy duty
+ 0.011 * (0.0934+ 0.00797)]}	motorcycle

= 454 kg yr^{-1}

Note this grid cell contains only one road type – arterial road.

12.0 Uncertainty Analysis

In the following discussion the reliability of data and other estimates is classified into 3 levels of confidence: high (uncertainty of 20% or less), medium (uncertainty of between 20% and 80%) and low (uncertainty of greater than 80%).

12.1 Data Reliability

Traffic and vehicle data provided by traffic authorities and the ABS are usually of high reliability. Traffic data estimated by traffic authorities and the ABS may not be entirely consistent with each other but differences are usually less than 20%. Population data provided by ABS is also of high reliability. However, since traffic does not necessary follow population distribution, emissions that are distributed by population are considered to be of medium reliability.

Fuel content and RVP data provided by oil companies or the AIP are of high reliability. Although fuel properties may vary from batch to batch, their difference is usually less than 20%.

Temperature data obtained from BOM is of high reliability. Since emission factors do not vary linearly with temperature and RVP, emission factors which are estimated for 12 months and averaged over a year are more accurate than those estimated from using annual averages of temperature and RVP.

12.2 Reliability of Emission Factors

Exhaust emission factors for CO, NO_x and VOCs for petrol-fuelled passenger vehicles are derived from vehicle test data obtained by EPANSW and EPA of Victoria. Data from a total of over 9000 tests on 2569 vehicles are available. Although emissions may vary greatly from vehicle to vehicle, the emission factors derived from these data are considered to be highly reliable for estimating annual average emissions.

However, there are no Australian test data for post-1996 vehicles, and estimates based on ratios of ADR emission standards are considered to be of only medium reliability.

Exhaust emission factors for other petrol and diesel-fuelled vehicles and evaporative emission factors are derived from MOBILE5a. Since emission factors derived from MOBILE5a are based on conditions in the USA, they are of medium reliability when applied in Australia.

Emission factors for LPG-fuelled vehicles are estimated from emission ratios of LPG and petrol-fuelled vehicles. These ratios vary from study to study and their reliability is considered to be medium.

Emission factors for PM_{10} from petrol and diesel-fuelled vehicles are derived from PART5. Since the emission factors derived from PART5 are also based on conditions in the USA, they are of medium reliability when applied in Australia. PM_{10} emission factors for LPG-fuelled vehicles are estimated from emission ratios of LPG and diesel-fuelled vehicles and are considered to be of medium reliability.

Emission factors for SO_2 and lead are estimated from the fuel content and fuel consumption rates of vehicle types. Emission factors derived from this mass balance approach are of high reliability.

Speciation factors for VOCs for petrol-fuelled vehicles are based on measurements on passenger and light commercial vehicles in Australia. Use of these speciation factors for all types of petrol-fuelled vehicles is considered to be of medium reliability. Speciation factors for diesel and LPG-fuelled vehicles are based on studies in the USA and Europe, and are of low reliability when applied in Australia.

Speciation factors for PM_{10} are based on US data and are considered to be of low reliability. It should be noted that metals and their compounds are speciated from PM_{10} rather TSP. The resulting error should be less than 10% since TSP is close to PM_{10} for most types of vehicles.

Correction factors are used for adjusting emission factors for different road types. These correction factors are derived from results obtained for petrol-fuelled passenger vehicles. Use of these factors for other vehicle types may not be accurate. For example, the emission factors estimated for petrol-fuelled light commercial vehicles on arterial roads and freeway are lower than those of petrol-fuelled passenger vehicles if such factors are used (see Table 11). Also, roads in different airsheds may have different characteristics. Use of these correction factors is considered to be of medium reliability.

Default emissions factors that are provided in this manual are based on national averages. Use of these default emission factors on a particular airshed is considered to be of medium reliability.

12.3 Problems and Issues Encountered

Since EPA ceased its vehicle testing program in 1993, no test data have been produced for post-1993 vehicles. Although new vehicle compliance testing is currently being carried at local manufacturers' testing stations, these results are confidential and not available to public. Estimates of emissions from post-1986, and to a lesser extent, 1987-1996 vehicles are hence less accurate than what would be the case if test data were available for post-1993 vehicles.

Emission testing for ADR purposes has often involved new cars or well-maintained cars of relatively low VKT. High emission vehicles which are generally not included in ADR test data may, however, be major contributors to total emissions.

The drive cycle employed in ADR testing may not represent real-world driving conditions where high accelerations, which results in very high CO and VOC emissions, are common. Other load factors, such as air conditioning, are also not accounted for in this methodology.

Emissions are comparatively very high when a post-1985 car is first started as the catalytic converter is still too cold to function optimally. The spatial distribution of these emissions from "cold starts" is usually concentrated in residential areas and car parks, and may be quite different from a distribution based on VKT. Although emissions from cold starts are included in the emission factors, their spatial distribution is not allocated accurately. Also, hot soak emissions, which occur mostly in car parks or at residences, are also not distributed accurately.

12.4 Recommendations for Further Work

There is a strong need for emission testing of in-service Australian vehicles under real-world conditions, including direct measurements of running and resting losses.

Emission and speciation factors for vehicles other than petrol and LPG-fuelled passenger vehicles, are usually drawn from US data. There is a need to develop Australian factors for these types of vehicles.

Australian studies of emissions from LPG-fuelled vehicles have so far been limited and inconclusive. Further study is required to obtain accurate emission factors for these vehicles.

13.0 Glossary of Terms and Abbreviations

ABS	Australian Bureau of Statistics
ADR	Australian Design Rule
AE	Aggregated emissions
AGPS	Australian Government Publishing Service
AIP	Australian Institute of Petroleum
BOM	Bureau of Meteorology
CO	Carbon Monoxide
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EET	Emissions estimation technique
EPANSW	Environment Protection Authority of New South Wales
EPAV	Environment Protection Authority of Victoria
GIS	Geographic information system
GVM	Gross vehicle mass
HC	Hydrocarbons
HDDV	Heavy duty diesel-powered vehicle
HDGV	Heavy duty gasoline-powered vehicle
LDDT	Light duty diesel-powered truck
LDDV	Light duty diesel-powered vehicle
LDGT	Light duty gasoline-powered truck
LDGV	Light duty gasoline-powered vehicle
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
MHDDV	Medium heavy duty diesel-powered vehicle
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NO_x	Oxides of nitrogen
NPI	National Pollutant Inventory
NSW	New South Wales
PAHs	Polycyclic aromatic hydrocarbons
PM_{10}	Particulate matter less than or equal to 10 µm
psi	Pounds per square inch
RVP	Reid Vapour Pressure: a common reference property (determined by a defined laboratory method) which is used to characterise fuel volatility
SAE	Society of Automotive Engineers
SAE-A	Society of Automotive Engineers, Australia
SO_2	Sulphur dioxide
TSP	Total suspended particulates
US	United States
USA	United States of America
USEPA	United States Environmental Protection Agency
VKT	Vehicle kilometres travelled
VMT	Vehicle miles travelled
VOC	Volatile organic compound

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15.0 Appendices

APPENDIX A: MOBILE5a INPUT FILE

APPENDIX B: PART5 INPUT FILE

APPENDIX A
MOBILE5A INPUT FILE

```
1          PROMPT
National motor vehicle emission factors for 2000.
1          TAMFLG
1          SPDFLG
3          VMFLAG - Supply one VMT mix for all scenarios.
4          MYMRFG - User supplied mileage accumulation and registration rates.
6          NEWFLG - User supplied basic exhaust emission rates.
1          IMFLAG
1          ALHFLG
1          ATPFLG
1          RLFLAG
1          LOCFLG
1          TEMFLG
6          OUTFMT - Spreadsheet format.
4          PRTFLG - Print all pollutants results.
1          IDLFLG
3          NMHFLG - Calculate emissions for volatile organic hydrocarbons.
2          HCFLAG - Print component HC emissions.
.723.111.000.004.028.044.080.010
.06927 .13983 .11597 .11403 .09520 .09562 .10815 .07826 .07188 .10499  LDGV miles
.07290 .06780 .09056 .07140 .07328 .08995 .07009 .06463 .10182 .06674
.12918 .05954 .05954 .05954 .05954
.07952 .13852 .14964 .14453 .13366 .13535 .12591 .11433 .12480 .11637  LDGT1 miles
.10427 .09811 .06768 .07723 .07161 .09115 .08191 .09077 .08915 .07355
.07842 .05745 .05745 .05745 .05745
.13005 .12718 .12553 .12490 .14900 .13221 .12224 .13725 .10887 .09774  LDGT2 miles
.12135 .04796 .10911 .06017 .07802 .14287 .04714 .06050 .04293 .03985
.02380 .02590 .02590 .02590 .02590
.13005 .12718 .12553 .12490 .14900 .13221 .12224 .13725 .10887 .09774  HDGV miles
.12135 .04796 .10911 .06017 .07802 .14287 .04714 .06050 .04293 .03985
.02380 .02590 .02590 .02590 .02590
.04106 .13103 .40730 .06894 .08824 .07045 .21145 .06276 .10293 .08793  LDDV miles
.15386 .22369 .07833 .08534 .08207 .03828 .00000 .02363 .00000 .00000
.00000 .02605 .02605 .02605 .02605
.09471 .17090 .15538 .17058 .16233 .13022 .14353 .13838 .13788 .11984  LDDT miles
.11441 .11474 .13667 .08102 .09869 .09518 .09220 .10062 .08545 .14482
.00000 .05503 .05503 .05503 .05503
.26055 .39214 .39950 .29016 .26470 .27368 .27764 .30037 .26753 .23578  HDDV miles
.24183 .19198 .19767 .18590 .17688 .17562 .18550 .17089 .19167 .12490
.07503 .06203 .06203 .06203 .06203
.03733 .04537 .03533 .02576 .04286 .02630 .03794 .02763 .02463 .03756  MC miles
.02787 .03334 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000
.00000 .00000 .00000 .00000 .00000
.025 .063 .059 .054 .050 .045 .065 .032 .038 .056      LDGV reg.
.048 .057 .043 .049 .056 .035 .032 .028 .028 .026
.011 .025 .025 .025 .025
.026 .059 .046 .045 .043 .045 .053 .053 .030 .037      LDGT1 reg.
.069 .057 .039 .047 .059 .044 .033 .038 .030 .024
.023 .025 .025 .025 .025
.005 .008 .009 .011 .012 .012 .010 .005 .008 .005      LDGT2 reg.
.019 .013 .013 .020 .024 .029 .042 .046 .049 .053
.066 .135 .135 .135 .135
.005 .008 .009 .011 .012 .012 .010 .005 .008 .005      HDGV reg.
.019 .013 .013 .020 .024 .029 .042 .046 .049 .053
.066 .135 .135 .135 .135
.025 .063 .059 .054 .050 .045 .065 .032 .038 .056      LDDV reg.
.048 .057 .043 .049 .056 .035 .032 .028 .028 .026
.011 .025 .025 .025 .025
.026 .059 .046 .045 .043 .045 .053 .053 .030 .037      LDDT reg.
.069 .057 .039 .047 .059 .044 .033 .038 .030 .024
.023 .025 .025 .025 .025
.014 .053 .041 .050 .036 .060 .071 .054 .045 .057      HDDT reg.
.073 .053 .030 .048 .049 .049 .037 .031 .024 .028
.019 .019 .019 .019 .019
.036 .081 .056 .046 .033 .040 .069 .028 .036 .049      MC reg.
.080 .447 .000 .000 .000 .000 .000 .000 .000 .000
.000 .000 .000 .000 .000
009                                                    BER records to follow
1 1 1 60 75 03.924 3.1E-4 3.1E-4                       Low-alt LDGV, pre76, HC ZML,
DRs
```

```
1 1 1 76 85 02.580 2.2E-4 2.2E-4                       Low-alt LDGV, 76-85, HC ZML,
DRs
1 1 1 85 95 00.592 1.7E-4 1.7E-4                       Low-alt LDGV, post 85, HC ZML,
DRs
1 1 2 60 75 40.974 3.8E-3 3.8E-3                       Low-alt LDGV, pre76, CO ZML,
DRs
1 1 2 76 85 25.761 3.3E-3 3.3E-3                       Low-alt LDGV, 76-85, CO ZML,
DRs
1 1 2 85 95 07.961 2.7E-3 2.7E-3                       Low-alt LDGV, post 85, CO ZML,
DRs
1 1 3 60 75 04.163 -01E-4 -01E-4                       Low-alt LDGV, pre76, NOX ZML,
DRs
1 1 3 76 85 02.239 1.6E-4 1.6E-4                       Low-alt LDGV, 76-85, NOX ZML,
DRs
1 1 3 85 95 01.184 3.0E-4 3.0E-4                       Low-alt LDGV, post 85, NOS ZML,
DRs
1 97 19.6 59.0 20.6 27.3 20.6 07                       Scenario description record
Annual           C  50.  68. 10.0 10.0 20              Local Area Parameter record
00000000000000000000000000000000000000000000000000000000000000000000000000000000000
```

APPENDIX B
PART5 INPUT FILE

```
National motor vehicle PM10 emission factors for 2000
3      :VMFLAG (alternate VMT mixes)
4      :MYMRFG (alternate mileage accumulation rates and registration)
1      :IMFLAG (Inspection and maintenance)
1      :RFGFLG (2 to apply reformulated gasoline effects, 1 not to)
3      :OUTFMT (indicates type of output format)
1      :IDLFLG (2 to print, 1 not to print idle emission factors)
1      :SO2FLG (2 to print Gaseous SO2 emissions, 1 not to print them)
3      :PRTFLG (determines which pollutants to print out)
1      :BUSFLG (determines which alternative bus cycles to print out)
0.7223 0.1110 0.0000 0.0043 0.0097 0.0278          :VMT MIX
0.0439 0.0000 0.0000 0.0719 0.0000 0.0091          :VMT MIX
.06927 .13983 .11597 .11403 .09520 .09562 .10815 .07826 .07188 .10499
.07290 .06780 .09056 .07140 .07328 .08995 .07009 .06463 .10182 .06674
.12918 .05954 .05954 .05954 .05954                             LDGV
.07952 .13852 .14964 .14453 .13366 .13535 .12591 .11433 .12480 .11637
.10427 .09811 .06768 .07723 .07161 .09115 .08191 .09077 .08915 .07355
.07842 .05745 .05745 .05745 .05745                             LDGT1
.23014 .13425 .12184 .12611 .12812 .13246 .11929 .11614 .10949 .08535
.11750 .04991 .11241 .05185 .07696 .15129 .04559 .05988 .04152 .04071
.02378 .02441 .02441 .02441 .02441                             LDGT2
.23014 .13425 .12184 .12611 .12812 .13246 .11929 .11614 .10949 .08535
.11750 .04991 .11241 .05185 .07696 .15129 .04559 .05988 .04152 .04071
.02378 .02441 .02441 .02441 .02441                             HDGV
.03733 .04537 .03533 .02576 .04286 .02630 .03794 .02763 .02463 .03756
.02787 .03334 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000
.00000 .00000 .00000 .00000 .00000                             MC
.04106 .13103 .40730 .06894 .08824 .07045 .21145 .06276 .10293 .08793
.15386 .22369 .07833 .08534 .08207 .03828 .00000 .02363 .00000 .00000
.00000 .02605 .02605 .02605 .02605                             LDDV
.09471 .17090 .15538 .17058 .16233 .13022 .14353 .13838 .13788 .11984
.11441 .11474 .13667 .08102 .09869 .09518 .09220 .10062 .08545 .14482
.00000 .05503 .05503 .05503 .05503                             LDDT
.30118 .42220 .43640 .30240 .27481 .28024 .28128 .30914 .26545 .23227
.24406 .19207 .19500 .18339 .17486 .17333 .18235 .17061 .19022 .12315
.07007 .05503 .05503 .05503 .05503                             2BHDDV
.30118 .42220 .43640 .30240 .27481 .28024 .28128 .30914 .26545 .23227
.24406 .19207 .19500 .18339 .17486 .17333 .18235 .17061 .19022 .12315
.07007 .05503 .05503 .05503 .05503                             LHDVM
.30118 .42220 .43640 .30240 .27481 .28024 .28128 .30914 .26545 .23227
.24406 .19207 .19500 .18339 .17486 .17333 .18235 .17061 .19022 .12315
.07007 .05503 .05503 .05503 .05503                             MHDVM
.30118 .42220 .43640 .30240 .27481 .28024 .28128 .30914 .26545 .23227
.24406 .19207 .19500 .18339 .17486 .17333 .18235 .17061 .19022 .12315
.07007 .05503 .05503 .05503 .05503                             HHDVM
.10783 .23522 .20961 .21840 .20834 .20066 .23190 .24597 .25959 .27170
.20343 .17725 .20453 .19496 .21063 .17763 .18718 .15987 .18673 .13036
.09773 .13004 .13004 .13004 .13004                             BUSES
.025 .063 .059 .054 .050 .045 .065 .032 .038 .056
.048 .057 .043 .049 .056 .035 .032 .028 .028 .026
.011 .025 .025 .025 .025                          LDGV
.026 .059 .046 .045 .043 .045 .053 .053 .030 .037
.069 .057 .039 .047 .059 .044 .033 .038 .030 .024
.023 .025 .025 .025 .025                          LDGT1
.005 .008 .009 .011 .012 .012 .010 .005 .008 .005
.019 .013 .013 .020 .024 .029 .042 .046 .049 .053
.066 .135 .135 .135 .135                          LDGT2
.005 .008 .009 .011 .012 .012 .010 .005 .008 .005
.019 .013 .013 .020 .024 .029 .042 .046 .049 .053
.066 .135 .135 .135 .135                          HDGV
.036 .081 .056 .046 .033 .040 .069 .028 .036 .049
.080 .447 .000 .000 .000 .000 .000 .000 .000 .000
.000 .000 .000 .000 .000                          MC
.025 .063 .059 .054 .050 .045 .065 .032 .038 .056
.048 .057 .043 .049 .056 .035 .032 .028 .028 .026
.011 .025 .025 .025 .025                          LDDV
.026 .059 .046 .045 .043 .045 .053 .053 .030 .037
.069 .057 .039 .047 .059 .044 .033 .038 .030 .024
.023 .025 .025 .025 .025                          LDDT
.017 .049 .038 .046 .033 .060 .071 .052 .044 .059
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.075 .054 .030 .050 .052 .051 .037 .031 .025 .030
.020 .020 .020 .020 .020                              2BHDDV
.017 .049 .038 .046 .033 .060 .071 .052 .044 .059
.075 .054 .030 .050 .052 .051 .037 .031 .025 .030
.020 .020 .020 .020 .020                              LHDVV
.017 .049 .038 .046 .033 .060 .071 .052 .044 .059
.075 .054 .030 .050 .052 .051 .037 .031 .025 .030
.020 .020 .020 .020 .020                              MHDVV
.017 .049 .038 .046 .033 .060 .071 .052 .044 .059
.075 .054 .030 .050 .052 .051 .037 .031 .025 .030
.020 .020 .020 .020 .020                              HHDVV
.041 .078 .069 .078 .061 .062 .064 .058 .051 .035
.053 .043 .029 .034 .020 .041 .034 .026 .022 .013
.017 .017 .017 .017 .017                              BUSES
1 1997 1 19.6    : region, year, speed cycle, speed
04.3 05.1   2    : unpaved silt%, ind. silt g/m^2, WHEELFLG
140              : number of precip. days
annual           :scene name
10.   -- Particle size cutoff
6000
04
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